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RCRA FACILITY INVESTIGATION WORK PLAN

**NAVAL STATION ROOSEVELT ROADS
(PR-2170027203)
CEIBA, PUERTO RICO**

ADDITIONAL INVESTIGATIONS AT SWMU 9

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LIST OF ACRONYMS AND ABBREVIATIONS

BTAG	Biological Technical Assistance Group
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CMS	Corrective Measures Study
EPA	Environmental Protection Agency
FY	Fiscal year
HHRA	Human Health Risk Assessment
IDW	Investigation Derived Waste
LNAPL	Light Non-Aqueous Phase Liquid
MCLs	Maximum Contaminant Levels
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NOAA	National Oceanic and Atmospheric Administration
OU	Operable Unit
PID	photo ionization detector
pvc	poly-vinyl chloride
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SOPs	Standard Operating Procedures
SWMU	Solid Waste Management Unit
TPH	Total petroleum hydrocarbons
USEPA	United States Environmental Protection Agency

1.0 INTRODUCTION

This work plan has been prepared to perform additional field investigation work at Naval Station Roosevelt Roads under the Corrective Action provisions of the Station's Resource Conservation and Recovery Act (RCRA) permit. The work plan addresses comments received from the United States Environmental Protection Agency (USEPA) in a June 15, 1998 letter (received June 18, 1998) regarding the draft Solid Waste Management Unit (SWMU) 9 RCRA Facility Investigation (RFI) Report (Baker, 1998).

Two previous phases of investigation have been completed at SWMU 9. The initial phase of work included all the investigations contained within EPA approved RCRA Facility Investigation Work Plans (Baker, 1995). Results of this work were provided in the Draft RFI Report for Operable Unit (OU) 2 (of which SWMU 9 was originally a part) (Baker, 1996). Comments were received from EPA (March 4, 1997 letter) which addressed the findings at SWMU 9. Based on the comments, a work plan for a second phase of investigations was prepared and submitted (Baker, 1997). This was approved in due course and the investigations were performed as "Phase II". The Phase I and Phase II data were combined and presented in the Draft RFI Report for SWMU 9 (Baker, 1998). The work described in this volume will constitute the third phase of investigations.

Specific elements of the investigations to be performed during Phase III include:

- A background soil and groundwater sampling program designed to provide site specific background for comparison purposes.
- A soil boring/groundwater program focused in certain areas (e.g. disposal pits, contaminated wells) to ascertain the extent of contamination, and
- An assessment of ecological risk posed by the SWMU using actual sampling data from proposed sediment and surface water locations.

When this work is completed, the results will be provided in a draft report. Once the site characterization information is complete and approved, the data from this investigation will be included in the SWMU 9 RFI report and finalized.

2.0 GOALS AND OBJECTIVES

The first two stages of investigatory work at SWMU 9 has provided much of the information needed to understand the environmental impact of operations at the site; however, the findings of the initial work has raised additional questions which need to be addressed before full conclusions regarding final site disposition can be made. It is the objective of the work described in this work plan to answer the remaining questions pertaining to site characterization and attendant risks to human health and the environment.

The goals of the investigations are related to the specific findings of the previous work. Each of these are discussed below.

2.1 Significant Findings

SWMU 9 has been sub-divided into three areas based on remote groupings of tanks comprising the SWMU. These have been designated Areas A, B and C. The discussion of findings uses these designations.

Area A (comprised of the area containing Tanks 212 and 213 and including well 9MW02R) has had a number of data gaps identified as follows:

1. Well 9MW02R was originally intended to be a background sampling point for Areas A and B. During drilling, a petroleum odor was noted and groundwater sampling confirmed the presence of significant levels of benzene and toluene. The extent of this contamination has not been established.
2. Groundwater elevation information is needed to understand groundwater flow directions in the area of 9MW02R and how they may relate to Areas A and B.
3. The potential usability of the uppermost aquifer as a drinking water source has not been established.
4. Metals concentrations in soil and groundwater exceed the background values established at the Base perimeter.

5. Sampling at well 13GW02 indicated the presence of benzene above Maximum Contaminant Levels (MCLs). The extent of the contamination has not been established.

Area B (comprised of the area containing Tanks 214 and 215) also has been identified as having data gaps. These are:

1. Metals in groundwater and soils exceed the concentrations in the Base background dataset.
2. Sampling results at 13GW05 indicated the presence of benzene above MCLs. The extent of the contamination has not been established.
3. Sampling results at 9TP02 and nearby well 13GW06 indicated the presence of semi-volatile organics at significant levels. Also in the general area of these two sampling points, a disposal pit has been identified. The extent of any contamination around 9TP02 and 13GW06 has not been established nor has direct sampling of the disposal pit been performed.

Area C (comprised of the area surrounding Tanks 216 and 217) also has been identified as having data gaps. These are:

1. Two organic constituents were detected, one each in widely separated wells. The extent of these occurrences has not been established.
2. Cadmium in groundwater at one location was above values established in the background dataset.

There were also two general areas where information is needed. One is related to ecological risk. Based on the findings of the initial investigations, it appears that some contamination is present that could cause adverse effects to environment. The potential ecological risks need to be established. Second, the tanks are subject to 40 CFR 280. Compliance with these statutes has not been documented.

2.2 Investigation Goals

This workplan proposes a series of investigations designed to address the concerns of the EPA and to close data gaps which exist at the site. The goals of the program, and how they are to be reached, are briefly discussed for each area in the paragraphs which follow.

The goals for Area A are:

1. Establish the extent of the benzene and toluene "plume" in the area of 9MW02R. This will be accomplished through a boring program during which soil and groundwater samples will be obtained in concentric rings around 9MW02R.
2. Establish groundwater flow directions through the interpretation of groundwater elevation measurements to be obtained in existing wells and proposed temporary piezometers.
3. Establish a site-specific background for soil and groundwater through a drilling and sampling program at the perimeter of SWMU 9. This will provide a comparison data set for onsite sampling results.
4. Establish the general quality of the uppermost aquifer in terms of its usability as a potable water source. This will be accomplished by analyzing certain groundwater samples for the "National Secondary Drinking Water Regulations" (40CFR, Part 143) parameters.
5. Establish the extent of benzene contamination, if it is found to be present areally, at well 13GW02. This will be accomplished through a boring program during which soil and groundwater samples will be obtained and analyzed from borings placed at varying distances downgradient of 13GW02.

The goals for Area B are:

1. Establish a site-specific background for soil and groundwater through a drilling and sampling program at the perimeter of SWMU 9. This will provide a comparison dataset for onsite sampling results.
2. Establish the extent of benzene contamination, if it is found to be laterally extensive, at well 13GW05. This will be accomplished through a boring program during which

soil and groundwater samples will be obtained and analyzed from borings placed at varying distances downgradient of 13GW05.

3. Establish the extent of semi-volatile organic contamination, if it is found to be laterally extensive, downgradient of 9TP02 and 13GW06. This will be accomplished through a boring program during which soil and groundwater samples will be obtained and analyzed from locations progressively downgradient of the test pit and monitoring well. Also, the area of the disposal pit will be directly investigated using a boring directly through the area.

The goals for Area C are:

1. Establish a site-specific background for soil and groundwater through a drilling and sampling program at the perimeter of SWMU 9. This will provide a comparison dataset for onsite sampling results.
2. Establish that the two semi-volatile constituents found are laboratory/sampling artifacts. This will be demonstrated through the resampling of the wells.

Additional general goals of the investigations are:

1. Establish the ecological risk posed by the contamination seen at SWMU 9. This will be done by:
 - collecting sediment and surface water samples
 - identifying potential receptors, and
 - comparing sampling data to EPA Region III Biological Technical Assistance Group screening levels.
2. Establish that tanks 212 through 217 are in compliance with 40 CFR, part 280. This will be accomplished through a records review.

Details of all the investigations to be performed are provided in Section 3.0 of the workplan.

3.0 TECHNICAL APPROACH

This section of the work plan describes the technical elements of the investigations needed to accomplish the goals described in Section 2.0

3.1 Basis of the Work Plan

The USEPA has approved a RCRA Facility Investigation (RFI) work plan for the initial work at Roosevelt Roads under the Corrective Action program (Baker, 1995). This work plan addressed all the necessary technical elements including provision of the following separate plans:

- Project Management Plan
- Data Collection Quality Assurance Plan
- Data Management Plan, and
- Health and Safety Plan.

Together, these plans provided all the details regarding field investigatory techniques, laboratory analyses, data validation and data evaluation needed to fulfill the requirements of the RFI program. Since this document is in place and approved, it will form the basis of this work plan. All the investigatory tasks described in subsequent sections of this plan will be performed in accordance with the techniques and methodologies provided in the original approved plan. Therefore, only the work elements themselves are discussed in the sections which follow.

3.2 Additional Site Characterization - SWMU 9

3.2.1 Background Sampling

Site Context

Exceedances of the base-wide background values have been encountered for certain inorganic constituents in the soil. It is the Navy's contention that the inorganics are present in the soil as a direct result of their being derived from volcanic rocks. Supporting information for this contention can be found in Appendix A. This information gathered from readily available literature indicates that the

constituents seen in the on-site soils and groundwater are naturally occurring sometimes at significant concentrations. Also, the site has been strictly used for petroleum product storage and not for the management of any other chemicals or wastes. These facts notwithstanding, a site specific background will be developed for surface soil, subsurface soil, and groundwater.

Investigations Proposed

A total of five background soil/groundwater sampling locations are proposed. Four of the locations are shown on Figure 3-1 while the fifth, in Area "C", is shown on Figure 3-4. Samples will be obtained using Hydropunch® equipment. A sample from the first one-foot below ground surface and the sample from immediately above the water table will be submitted to the laboratory for analysis of Appendix IX metals and metalloids. The laboratory results will be validated by an independent, third-party, data validation firm.

A groundwater sample will be obtained at each location. The samples will be analyzed for volatile and semi-volatile organics and total and dissolved Appendix IX metals and metalloids. The results will be independently validated.

Investigations Rationale

A number of background samples for soil and groundwater were selected based on two needs:

1. Areal distribution of samples to ensure that all areas are represented, and
2. Provide a large enough data population that would be representative of natural conditions.

Five sample locations were selected to provide a representative areal distribution of points. Four of the locations are associated with Areas A and B and represent the nearest points available that are sufficiently away from the SWMU to be unaffected by site activities. One background location was established in Area C, again sufficiently away from site activities to be unaffected yet close enough to be representative of site conditions, to assess whether the relative remoteness of Area C results in different soil/groundwater characteristics.

Five samples will also provide a suitable statistical population for development of a site-specific background. The intent is to provide a sufficient number of samples, from areas representative of site characteristics, to impart natural variability in constituent concentrations into the background database. This will allow the comparison of site data to background to be made with less possibility of false negatives or positives being encountered.

At each of the five locations, a surface soil, a subsurface soil and a groundwater sample will be obtained. This pattern of sampling mirrors that used for on-site sampling in the SWMU. The samples also correlate to the media assessed for human health (i.e.: surface and subsurface soil and groundwater). Collection of this background information will allow direct correlations to be made with site data.

Soils for the background will be analyzed for Appendix IX metals and metalloids. No volatile or semi-volatile organics are to be analyzed for, since the only questions related to the soil from the initial investigations was related to these constituents. Volatile and semi-volatile organics will be analyzed in groundwater (along with Appendix II metals) to assess whether they are present in the background.

Data Usage

The average concentration for each constituent detected in the site-specific background will be determined and multiplied by two. Multiplying the average background value by two will provide comparison criteria that reflect natural variability in constituent concentrations and which will limit false positive detections while still having the capability of detecting significant exceedances. The resulting values will be used to compare to site data for purposes of determining whether the inorganic constituents seen are naturally occurring. This approach has been taken from EPA Region IV guidance (USEPA, 1995). The new site-specific background will also be compared to the existing background to ascertain whether obtaining site-specific information results in a more comparable background dataset.

3.2.2 Area "A" Investigations

Site Context

Two continuing areas of concern were found to be present after the first two phases of investigatory work. There is an area of elevated benzene concentration (130ug/L) in the vicinity of monitoring well 13GW02. This area of benzene occurrence was documented in the report; however, the extent of its occurrence was not established since there was no evidence of a problem during the field investigations. It was only upon receipt of the validated data that the problem was identified. EPA has, in their comments, requested additional characterization in the area of 13GW02 to delineate the extent of the benzene occurrence.

Well 9MW02 was installed during the Phase I investigations just off the access road to Areas A and B at a point remote to each operational area. The location should have been free of effect from site operations. The well was installed with the intent to have the well screen straddle the water table which would allow any light non-aqueous phase liquid (LNAPL) to freely enter the well. Final equilibrated water levels were found to be significantly higher than the apparent occurrence of water in the boring would have indicated. This resulted in complete inundation of the well screen.

Well 9MW02R was installed during the second phase of investigations to remedy the situation. The replacement well (hence the "R" designation) was installed in approximately the same location as well 9MW02 which was abandoned by overdrilling leaving only the replacement well (9MW02R) operable.

9MW02R was sampled during the second phase of investigations. A petroleum odor was noted during drilling and benzene and toluene were found in the groundwater at levels significantly above the federal MCLs. EPA has requested additional investigations in the area of 9MW02R to delineate the extent of the groundwater contamination.

The contamination found in 9MW02R was unexpected since the well was in a background location and was situated well away from the tanks and operational areas. Now that it is known that there is contamination present, the direction of flow in the vicinity of 9MW02R is of considerable more interest. Assessing the flow directions is important in understanding where the plume associated with 9MW02R may be migrating.

Investigations Proposed

Well 13GW02 Area

Two Hydropunch® locations are shown on Figure 3-2 50 feet topographically downslope (and therefore likely downgradient) from the well. The Hydropunch® equipment will be driven through the soil until groundwater is encountered. There will be no soil samples obtained. A sample of the groundwater will be obtained and analyzed in an on-site, mobile laboratory for benzene, toluene, ethylbenzene and xylene (BTEX). In addition, Well 13GW02 will also be sampled and analyzed for BTEX. Throughout the Phase III investigation program, one Hydropunch® sample of each four will be taken as duplicates with one portion submitted to a mainland analytical laboratory. The results of the mainland laboratory analysis will be independently validated to provide a quality check for the on-site lab.

If one or both of the two samples indicate the presence of BTEX constituents, additional Hydropunch® locations will be employed at a distance of 150 feet from the well as shown on Figure 3-2. These will be sampled and analyzed in the same manner. Should the outermost ring of hydropunch locations indicate the presence of benzene, no additional sampling will be required due to the nearness of the surface water.

In conjunction with the Hydropunch® work, well 13GW02 will be resampled with the sample analyzed in the on-site laboratory. This will provide a time-equivalent "snapshot" of area ground water conditions.

9MW02R Area

The first step in addressing the 9MW02R area will be to review available site utility and product pipeline maps. Special attention will be paid to pipelines and associated clean-outs, valve boxes etc. to ascertain the possible source of the contamination seen in the well. In addition, fuel workers will be interviewed to determine if repair work on pipelines was performed in this area in the past. Finally, the results on any pipeline pressure testing will be sought to see if this information can shed any light on the possible source of contamination.

The area around 9MW02R will be investigated using Hydropunch® equipment. Twelve Hydropunch® locations are shown on Figure 3-2 with three points 50 feet from the well, three at 100 feet and six at 200 feet. The 50 foot, 100 foot and the three 200 foot locations shown as Hydropunch® piezometers will be advanced as a part of the initial work starting with the holes closest to 9MW02R and moving outwards.

At each location, a soil sample will be obtained from the zone immediately above the water table. This corresponds to the same soil horizon where contamination by BTEX constituents were found in borings made for earlier investigations. These samples will be sent to a mainland laboratory for analysis of BTEX and Total Petroleum Hydrocarbons (TPH).

A groundwater sample will be taken from 9MW02R and each of the nine Hydropunch® locations included in the initial effort. These samples will be analyzed on-site for BTEX. Depending on the results of the analyses, the remaining locations on the 200 foot ring may be advanced and sampled depending on apparent plume migration direction. If the 200 foot locations continue to exhibit contamination, discussions will be held with the EPA to determine any further steps that may be required.

The three Hydropunch® piezometer locations will be advanced and sampled as the others. When complete, a small diameter poly-vinyl chloride (pvc) temporary monitoring well will be placed in the hole extending into the groundwater. This approach will allow the locations to serve as temporary groundwater elevation measurement points. The information from the piezometers will be used to assess groundwater flow directions.

In summary, the following order will be followed in performing the investigations in the 9MW02 R area:

- Three hydropunch sampling points will be placed 50 feet from the well
- Three will be placed at 100 feet from the well
- Three will be placed at 200 feet from the well (to be temporary piezometers)
- If contamination is seen at 200 feet from the well, up to three additional points will be established at 200 feet
- Should contamination extend beyond 200 feet, EPA will be consulted

Investigations Rationale

Well 13GW02 Area

Well 13GW02 contained 130 µg/l benzene in the groundwater. A boring program has been proposed that will utilize the relatively lesser intrusiveness of the hydropunch technology coupled with an on-site laboratory to provide an immediacy of analytical results. This will allow the investigations to "react" to sampling results while the crew and equipment are still in the field.

The area around 13GW02 itself is relatively flat; however, the ground slopes strongly away from the well within 25 feet in the direction of Vieques Sound/Atlantic Ocean. Based on the topography, the water table is inferred to have a primary flow direction of downslope towards the open water. The borings proposed have been strategically placed so as to intercept this primary direction of flow.

Borings are proposed for a distance of 50 feet from the well. If contamination is found, additional sampling points will be established at a distance of 150 feet. Should contamination be found in the 150 foot locations, no additional sampling will be performed. Beyond the 150 foot line, the slope significantly increases rendering additional sampling locations infeasible. Also, the nearness of open water also negates the need for further sampling.

Analysis of the groundwater will be for BTEX only. This will allow the detection of benzene, which was the only organic found in 13MW02, as well as the additional fuel parameters which are often associated with benzene. No soil samples will be obtained since there was no soil contamination seen in this area during previous investigations. Well 13GW02 will be sampled in conjunction with the first hydropunch sampling. Analyzing this sample for BTEX will establish whether benzene is still present in the well or whether its original occupancy was transitory.

9MW02R Area

The same general investigatory approach as that proposed for the 13GW02 area will be utilized here except that more extensive sampling is proposed since the apparent contamination is more severe in the 9MW02R area. Also, the intent of the investigations in this area is threefold:

1. To identify, if possible, a source for the benzene and toluene
2. To establish the extent of contamination, and
3. To establish groundwater flow directions.

Each of these is discussed in the paragraphs which follow.

A review of available drawings will be made to see if a source for the contamination seen in the area of 9MW02R can be identified. Also, fuels department employees will be interviewed to see if there are any remembrances of incidents in the past which could have led to the contamination seen in the area. At the present time, the working hypothesis is that the contamination arises from a past leak from a pipeline. This is intuitively thought since it would only be reasonable to expect a pipeline to follow the same route as the access road.

The extent of the contamination will be established through on site analysis of samples obtained at points progressively further away from the location of 9MW02R. This approach will allow the extent of any plume to be established during this phase of investigations thus eliminating the need for additional work.

The rise of groundwater elevation measurements taken in the existing wells and the temporary hydropunch piezometers will provide sufficiently detailed information to establish groundwater flow directions throughout Areas A and B of SWMU 9. Knowing the direction of groundwater flow will allow predictions to be made regarding the direction of possible contamination migration enabling the field investigations to be modified accordingly.

Data Usage

Information obtained from the investigations around 13GW02 will be assessed to determine if a plume of contamination is present in the vicinity. The human health risks will be recalculated for all of Area A using the newly acquired sampling data. If a contaminant plume which poses significant risk is found, the data from this program will be used during the Corrective Measure Study (CMS) to aid in the selection of the appropriate remedial alternative.

The extent of the plume of contamination in the area of 9MW02R will be identified. A source for the contamination will attempt to be identified based on interviews with employees and utility/pipeline maps. The hydraulic relationship of 9MW02R to Areas "A" and "C" will be established through the measurement of groundwater elevations in existing wells and the Hydropunch® piezometers. Based on the results of the investigation, an assessment of human health risks will be performed for all of Area A. Final analysis of the risks and the extent of contamination will provide the basis for conclusions regarding site disposition.

3.2.3 Area "B" Investigations

Site Context

Two specific areas within Area "B" are of interest: The area around well 13GW05 where benzene in groundwater was found, and the area around 9TP02 and well 13GW06 where semi-volatile organics were found also in groundwater. Each of these areas is separately addressed through a tailored Hydropunch® investigation program described in the paragraphs which follow.

Investigations Proposed

13GW05

Two initial sampling locations have been selected as shown on Figure 3-3. These locations, located 50 feet downgradient, are designed to intercept any contamination which is flowing away from the well in the directions most likely to receive flow based on the previous groundwater investigations and the site topography. Hydropunch® equipment will be advanced into the groundwater and a sample will

be obtained. The sample will be analyzed for BTEX in the on-site laboratory. In addition, a groundwater sample will be obtained from 13GW05 and analyzed for BTEX on-site.

Three provisional sampling locations are shown on the figure in a downgradient ring 100 feet from the well. These sites will have groundwater sampling performed (using Hydropunch® equipment) only if the results of the first samples indicate the migration of contaminants away from the well.

13GW06, 9TP02, and the Disposal Pit Area

A total of four groundwater sampling locations are proposed as shown on Figure 3-3. These locations were selected to intercept groundwater flow away from the area and were chosen based on previous groundwater information and the topography of the site which slopes away to the east and southeast. All the locations will be investigated using Hydropunch® equipment. At each sampling site, the Hydropunch® will be advanced into the groundwater and a sample obtained. The samples will be analyzed for BTEX and semi-volatile organics in the on-site laboratory as these were the constituents detected in the earlier investigations. In addition, a sample will be obtained from 13GW06 and similarly analyzed.

The sampling location that is within the projected area of the Disposal Pit will be used to obtain a groundwater sample as previously indicated and also to obtain up to two soil samples. The first sample will be taken in soil that exhibits petroleum or other contamination [either visually, olfactorily, or on the photo-ionization detector (PID)]. Samples will be analyzed for BTEX and semi-volatile organics. If no apparent contamination is identified - no sample in that interval will be obtained. A soil sample will be obtained from immediately above the groundwater table regardless of whether evidence of soil contamination is present.

Five provisional Hydropunch® sampling locations are indicated on the drawing (Figure 3-3). The northern and easternmost four are contingent on finding contamination in the 50 foot ring samples. If the northernmost 50 foot location exhibits positive detections of organics, the northeastern two additional points will be employed. If the 50 foot point nearest 9TP02 contains contamination, the middle two 100 foot points will be sampled. If the southernmost 50 foot point contains organics, the two southeastern points will be sampled. Finally, if any two of the 50 foot points contain contaminants, all four of the 100 foot points will be sampled. The 50 foot point southwestward from

the Disposal Pit will only be used if groundwater is found to be affected in the Disposal Pit sampling location.

For both areas within Area "B", if contamination is found in the 100 foot ring and it is not higher than that originally seen in the Phase I near source locations, no further samples will be taken and the groundwater will assume to discharge to the surface water at the 100 foot ring concentration.

Investigation Rationale

13GW05 Area

The approach to be employed at the 13GW05 area parallels that described previously. Two sampling points will be established at a point 50 feet away from the well downgradient of the well location. Groundwater flow direction has been interpreted based on topography, i.e. the ground rapidly slopes away from the well and it is likely that the groundwater surface mirrors the topography.

The samples from the first two borings will be analyzed in an on-site laboratory to provide nearly immediate results. Should BTEX compounds be found in either of the two new points, the three provisional locations will be investigated using the hydropunch equipment and on-site laboratory. Should contamination be found at these points, no further sampling will be performed. The nearness of surface water and the inaccessibility of the intervening area render additional sampling unnecessary.

13GW06, 9TP02 and Disposal Pit Area

The rationale for the selection of groundwater sampling points in this area is the same as used previously for other areas with the exception that semi-volatile organics will be added to the analyses. This step was taken to address the findings of the previous investigations during which a small number of semi-volatile organics were detected in the sampling results.

Data Usage

The data will be analyzed and the extent of contamination will be identified. Risks posed by any constituents found to be present will be assessed for both human health and the environment. Should contamination be seen to extend to the shore line, the need for additional monitoring wells will be assessed during the CMS stage (if required) of the RCRA Corrective Action program.

3.2.4 Area "C" Investigations

Site Context

Two organic constituents were detected, one each in two widely separated wells. One of the organics, bis (2-ethylhexyl) phthalate, is a common laboratory/sampling artifact since it is plasticizer used in laboratory and sample containers. Also, the chemical is not a constituent of petroleum products. 1, 2 Dichloropropane was found in another well at an estimated concentration of 2 ug/l. This is also often a laboratory artifact since it is an intermediate for carbon tetrachloride used in the laboratory for cleaning.

One well at the northern end of the site exhibited total and dissolved cadmium above screening levels.

Investigations Proposed

Wells number 13GW11, 13GW10 and 9MW04 will be resampled. Each sample will be submitted to the mainland laboratory for analysis as follows:

- 13GW11 - volatile organics
- 13GW10 - semi-volatile organics
- 9MW04 - cadmium

Laboratory results will be validated independently.

One Hydropunch® sampling location is proposed at the location shown on Figure 3-4. From this location, samples will be obtained from surface soils, from the soil immediately above the groundwater

table and from groundwater. Analyses, to be performed in the mainland laboratory, will be for Appendix IX metals. The resulting data will be subjected to third-party, independent validation.

Investigations Rationale

Investigations at this area largely amount to a resampling effort. Previous findings have indicated two single semi-volatiles, found in separate wells, at low levels, and cadmium found above the screening level in one well. The semi-volatiles are both common laboratory artifacts. Cadmium in one well was the only inorganic exceedance.

The following were considered in assessing the need for further investigations at the site:

- The site has only been used for the management of petroleum products - the semi-volatiles seen are not product constituents.
- Only two semi-volatiles were found, one each in two widely separated wells, which does not appear to indicate a widespread organic plume.
- The semi-volatiles were found alone - it is much more common to find a suite of organics present if the occurrence is related to releases, and
- Cadmium occurs naturally in soil and groundwater

Given these considerations, only confirmatory resampling is technically justifiable.

There is one boring proposed for the site. This is designed to provide information on background concentrations (primarily for inorganics) as a part of the site-wide background data development discussed previously.

Data Usage

The results of the resampling will be compared to the previous data to ascertain if the initial findings indicated real contamination or merely reflected the presence of laboratory artifacts. Should positive detections be confirmed, additional investigatory steps may be needed. These will be determined in consultation with EPA.

The results of the Hydropunch® sampling will be used to compare to site soil and groundwater and will be incorporated into the site specific background by combining with background samples from Areas "A" and "B".

3.2.5 Surface Water and Sediment

Site Context

Sporadic contamination has been identified in different areas of SWMU 9. Human health risks associated with the future resident scenario have been calculated from the Phase I and Phase II results; however, potential ecological risks have not been addressed. The investigations discussed in subsequent paragraphs provide for investigations designed to obtain supplemental information regarding site conditions that can assist in understanding ecological risks.

The data available from the first two phases of investigation has already been screened for ecological risk by comparing site data to published ecological criteria. Using worst case scenarios of the most contaminated groundwater discharging to the mangrove areas, indications are that some exceedances of the criteria are present. Given this, it was determined that direct sampling of surface water and sediments, and the subsequent use of this data in the screening process, would result in a more accurate assessment of potential ecological risks.

Investigations Proposed

Seven locations are proposed for sediment and surface water sampling. The sample locations are shown on Figures 3-1 and 3-4 and are distributed as follows:

- One sampling location north of Area "B" (Figure 3-1)
- One location west of Area "B" and north of Area "A" (Figure 3-1)
- One location northeast of Area "B" (Figure 3-1)
- One location east of Area "B" (Figure 3-1)
- Two locations northwest of Area "C" (Figure 3-4)
- One location far to the southeast of Areas "B" and "A" (Figure 3-1)

The location southeast of Areas "A" and "B" will serve as background for the remaining samples.

At each location, a sample of surface water will be obtained and analyzed for volatile and semi-volatile organics and Appendix IX metals in the mainland laboratory. A sediment sample will be obtained at the same location and analyzed for the same parameters. All analytical data will be validated.

Investigations Rationale

The entire intent of collecting surface water and sediment samples is to provide information to be used in assessing any ecological risks which may be present at the site. Receptors at the site are expected to include:

- On-site, terrestrial, flora and fauna,
- The mangrove areas immediately off shore,
- The benthic community in the mangrove area, and
- Species which feed on the benthic dwellers (and, diminishingly, species higher on the food chain).

Surface soil samples previously obtained provide a suitable database for the assessment of terrestrial ecological risks so, therefore, no additional sampling of soil is proposed.

Aquatic receptors are usually more sensitive and, for that reason, it is important to obtain samples of the actual media in which they dwell (i.e., surface water and sediments). Risks to aquatic receptors have been preliminarily screened using the highest levels of contamination seen in the groundwater and site soils. This is a worst case approach since it does not take into account transport leaching, dilution, natural attenuation, etc. of constituents which act on the media prior to becoming surface water or sediment. These concentrations were compared to published screening criteria and the results indicated that there were possible ecological risks. This result prompted the proposal for a full sampling of surface water and sediment so that comparisons can be made to actual values rather than ones that are not media specific.

Sampling locations (shown on Figures 3-1 and 3-4) have been selected to provide a representative picture of surface water and sediment quality in the areas immediately surrounding SWMU 9. Essentially, two samples have been proposed from each of the Areas A, B and C within the SWMU. While this is the intent, the samples from Areas A and B do overlap somewhat because of the common shoreline shared by sections of both.

The final location is well removed from any area that could be impacted by site activities. This location will serve as background. The data from the background location will be compared to the SWMU specific samples to ascertain what constituents of the water and sediment are naturally occurring.

The analyses selected address all the constituents of concern related to SWMU 9. These include the volatile and semi-volatile organics (some of which are associated with petroleum products) and the inorganic constituents of Appendix IX.

Data Useage

The validated data will be compared to ecological screening criteria to assess the potential for ecological risk. The screening criteria to be used will be those compiled by the USEPA Region III Biological Technical Assistance Group (BTAG). These screening criteria have been provided as Appendix B to this workplan. This group has representatives from Region III, National Oceanic and Atmospheric Administration (NOAA) and the Commonwealth of Virginia. The criteria have been called from various sources and represents the most complete and up to date set of values known to

be available. It should be noted that the use of these values has been discussed with, and agreed to by, EPA prior to the submission of this workplan.

3.2.6 Groundwater Quality

Each of the existing wells that has been indicated for resampling at Areas A, B and C (includes wells 13GW02 and 9MW02R in Area A, 13GW05 and 13GW06 in Area B and 13GW10, 13GW11, and 9MW04 in Area C) will be analyzed for the constituents indicated in the appropriate sections. In addition, these wells will also be sampled for:

•	Aluminum	7000 Series*
•	Odor	-----
•	Salinity	-----
•	Color	110.1**
•	TDS	160.1*
•	Fluoride	340.2**
•	Hardness	130.2**
•	Chloride	9250*
•	Iron	7000 Series*
•	pH (field)	-----
•	Manganese	7000 Series*
•	Corrosivity	Langlier Saturation Index
•	Sulfate	9035-38*
•	Copper	7000 Series*
•	Silver, and	7000 Series*
•	Zinc	7000 Series*

* "Methods for Chemical Analysis of Water and Wastes," USEPA, EPA 600/4-79-020. Revised March 1983.

** "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," USEPA. SW-846

These parameters comprise the National Secondary Drinking Water quality criteria as established in 40CFR, Part 143. These analyses will be performed in the mainland laboratory.

The data will be used to assess overall suitability of the uppermost aquifer to be used as a potable water source. While this is the case, the Base is presently served by a high quality and high capacity water source which is piped in from the rainforest. There is no intent to utilize the uppermost aquifer as a source of water.

3.3 Miscellaneous Investigation Considerations

This section contains some miscellaneous investigations and related work that are required for the work proposed in the previous sections.

3.3.1 Surveying

All sampling locations will be flagged in the field and will be surveyed for vertical and horizontal location using established control. This surveying will be performed by the firm which did the previous work to ensure that the same level of survey quality and detail is attained.

3.3.2 Laboratory Analyses

All analyses done in the mainland laboratory will be performed in accordance with the methodologies contained in the approved Final RCRA Facility Investigation, Naval Station Roosevelt Roads, Puerto Rico (Baker, September, 1995) Work Plans. Table 3-1 summarizes the samples to be obtained and the analyses to be performed.

It should be noted that many of the Hydropunch® groundwater samples will be analyzed in an on-site laboratory to provide almost immediate data which can be used to guide subsequent steps in the investigation. When an on-site lab is used, 25 percent of the samples (one out of four) will be collected in duplicate with the duplicate sent to the mainland lab for analysis and subsequent data validation. This approach will provide a check on the field laboratory's performance.

3.3.3 Data Validation

All mainland laboratory data generated by these investigations will be subjected to independent, third party, validation. The EPA Region II Data Validation Standard Operating Procedures (SOPs) agreed

to prior to full approval of the original RFI workplans will be followed. The same firm which has performed data validation for the previous RFI steps will continue. This will ensure that the same techniques are followed and that an equivalent review of the data is performed.

3.3.4 Field QA/QC

The approved RFI work plans will be followed which will include the collection of Quality Assurance/Quality Control (QA/QC) samples as appropriate. These will include the requisite number of :

- Duplicates
- Matrix Spike/Matrix Spike Duplicates (MS/MSDs)
- Trip Blanks
- Field Blanks, and
- Equipment Blanks

Complete chain-of-custody procedures will be followed.

3.3.5 Investigation Derived Waste (IDW)

Only three sources of minimal IDW are expected during these investigations:

- Purge water from the sampling of the existing wells
- Cuttings from the advancement of Hydropunch®
- Hydropunch® tool decontamination water

All waters will be disposed on the ground near the original source. The relatively limited areas of investigation and low levels of contamination indicates this is a technically adequate treatment of these waters. This approach has been used previously on Roosevelt Roads at certain SWMUs.

Cuttings from the advancement of Hydropunch®es will be mixed with powdered bentonite and placed back in the hole from which they came. As much as possible, soils last out of the hole will be returned

first, thereby, approximating original stratigraphy. This approach has been extensively used in the past for hydropunch investigation.

3.3.6 Standard Operating Procedures

All the SOPs applicable to this work are included in the original RFI work plans or subsequent addenda.

The following SOPs are incorporated into this workplan by reference:

- SOP F101 - Borehole and Sample Logging
- SOP F102 - Soil and Rock Sample Acquisition
- SOP F104 - Groundwater Sample Acquisition
- SOP F105 - Surface Water and Sediment Sample Acquisition
- SOP F110 - Direct Push Soil and Groundwater Sampling
- SOP F201 - On-Site Water Quality Testing
- SOP F202 - Water Level, Water-Product Level Measurements, and Well Depth Measurements
- SOP F203 - Photoionization Detector (PID), HNu Models PI 101 and DL 101
- SOP F208 - Bacharach Combustible Gas/Oxygen Meter and Personal Gas Monitor
- SOP F301 - Sample Preservation and Handling
- SOP F302 - Chain-of-Custody
- SOP F303 - Field Logbook
- SOP F304 - QA/QC Samples
- SOP F501 - Decontamination of Drilling Rigs and Monitoring Well Materials
- SOP F502 - Decontamination of Sampling and Monitoring Equipment
- SOP A008 - Filing

4.0 DATA EVALUATION

The data from the Phase III investigations (those described herein) will be combined with those from the first two phases to provide a unified data base. This information will be used to establish the following:

- Background soil and groundwater conditions as they relate to site data
- Groundwater flow directions (assist in understanding potential contaminant migration pathways)
- The risk to human health, based on site specific sampling results
- The potential risk to the environment, based on comparison of site sampling results to EPA Region III BTAG screening criteria
- The quality of site groundwater in terms of its ability to be used as a potential source of drinking water

Each of these is discussed in the sections which follow.

4.1 Background

An extensive program of background sampling has been proposed. The intent is to obtain a site-specific background, based upon a sufficient number of samples to be statistically significant, that can be compared to site data to aid in understanding what apparent contaminants may actually be site related. This program is designed to address the inorganic constituents which were found during the initial investigatory work.

The site-specific background data will be combined based on media and depth and an average concentration determined for each constituent of concern. Site data will be screened against twice the average background and the maximum detection in background. This approach follows recent USEPA Region IV guidance (EPA, 1995).

4.2 Groundwater Flow and Quality

Groundwater flow directions are important in assessing potential contaminant migration pathways. The data from the measurement of groundwater elevations in the existing wells, the Hydropunch® sampling points and the Hydropunch® piezometers will be used to understand groundwater flow. In addition, the location of the screen intervals of each well will be compared to groundwater elevations to insure they straddle the water table.

Appropriate piezometric head contour maps will be developed and flow directions will be interpreted.

As indicated previously, secondary groundwater quality parameters will be analyzed for in a number of samples. The results of these analyses will be compared to the USEPA secondary drinking water criteria to assess the potential for the uppermost aquifer to be used as a potable water source. No program to establish specific capacity, transmissivity or yield is planned.

4.3 Human Health Risk Assessment (HHRA)

A HHRA will be performed on the combined data set. Two important differences will be obvious in the assessment as compared to the original one performed for the draft RFI SWMU 9 report (which presented the results of Phase I and II investigations) (Baker, 1998).

First, the intent is to perform separate HHRAs for each area (ie. Area "A", "B" and "C"). The widely separated nature of these sites indicate that they would not be remediated together (that is, the timing might be the same but each site would have to be treated as a separate entity), nor does each present similar risks. This approach will allow a better understanding to be attained of the risk posed by each site within SWMU 9 boundaries.

Second, USEPA guidance calls for all constituents that exceed criteria to be evaluated in the HHRA regardless of their concentration in the background. This will be done in accordance with guidance; however, a section will be added to the HHRA which compares constituent concentrations that drive unacceptable risk in site samples to the background database to qualitatively assess whether similar risks are posed by background conditions.

4.4 Ecological Risk Screening

Potential ecological impacts due to possible contaminants released at this SWMU have not been investigated. This work plan proposes an ecological risk screening for each site to assess the likelihood that adverse ecological effects would occur or are occurring as a result of receptor exposure to contaminated media.

Because no previous ecological investigations have occurred in this area and there are no indications of ecological distress, it is proposed that an ecological screening for terrestrial and aquatic receptors on or adjacent to SWMU 9 be conducted on the site sampling data. Three ecological pathways will be evaluated: surface soil, surface water, and sediment. This assessment will be conducted on new and existing surface soil data collected from the SWMU and surface water and sediment data to be collected in the mangrove area adjacent to the SWMU as described in previous sections.

The ecological screening will include the following components: a qualitative identification of the habitats potentially impacted by contaminants (based on a literature search); identification of any sensitive species expected to inhabit this area; a screening of media concentrations against Region III BTAG screening levels; establishment of ecological toxicological profiles for the primary contaminants of concern identified in the screening; a comparison of media concentrations to acceptable background data; and a risk management decision of the ecological screening to determine if further ecological investigation is warranted.

The risk screening methodologies will be guided by the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA, 1998) and the Tri-Service Procedural Guidelines for Ecological Risk Assessment (U.S. Army Edgewood Research et al., 1996).

The ecological risk screening will contain the following sections:

- Selection of ecological contaminants of concern
- Exposure assessment
- Toxicity assessment

- Risk characterization
- Uncertainty analysis

A brief description of these sections is provided below:

Selection of Ecological Contaminants of Concern

Ecological contaminants of concern will be selected by screening surface soil, surface water, and sediment concentrations against screening levels established by the USEPA Region III Biological Technical Assistance Group (BTAG). These screening levels are provided in Appendix B of this work plan. Where BTAG screening levels are not available, the constituent will be qualitatively screened against other published criteria if available. The contaminants and media of concern identified in this selection process will be carried through the risk evaluation.

Exposure Assessment

This step of the ecological evaluation will include an estimation of contaminant levels and the biological receptors potentially exposed to the contaminants. For this exposure assessment, hazard quotient values will be calculated using the maximum concentrations detected in the media sampled for the ecological investigations.

Toxicity Assessment

Ecological toxicological profiles will be formulated for the contaminants of concern identified for each pathway. This toxicity assessment will provide information on the types and potential impacts to the habitat of the contaminants detected in the surface soil, surface water, and sediment.

Risk Characterization

Risk characterization is the final phase of the ecological study and integrates the results of the exposure and toxic assessments. The likelihood of adverse effects occurring as a result of exposure to a stressor will be evaluated. The values from the soil, sediment, and groundwater will initially be assessed for ecological effect without comparison to background. A second comparison will be made

using the site-specific background. In this comparison, only the constituents which do not occur naturally will be used to assess risk to the environment.

Uncertainty Analysis

This proposed ecological risk screening is subject to a wide variety of uncertainties which are inherent to the process as established in the guidance. Every step of this screening process involves numerous assumptions that contribute to the total uncertainty in the ultimate evaluation of risk. The uncertainty analysis will attempt to address the factors that affect the results of the ecological risk screening.

5.0 REPORTING

The Phase III investigations will be included in a revised draft RFI report. This report will contain a description of the field investigations performed, the results of the sampling and analysis, and evaluations of the Phase I, II and III combined data. The data will be displayed on appropriate graphs and maps (eg. isopleths of concentration, potentiometric surface maps).

Conclusions and recommendations for further work (if deemed necessary) will be provided in the report by area. At this juncture the need (or lack, thereof) for a formal CMS will be established. [Note: the need for additional, permanent, monitoring wells at any of the areas will be addressed during the CMS process.] The recommendations will be based on the conclusions which will, in turn, be based on the interpretation of the data, the ecological risk screening and the HHRA.

On June 18, 1998, the Navy received a comment letter from USEPA regarding the Draft RFI (Baker, 1998) report for SWMU 9. These comments have been responded to in the cover letter to this workplan. Many of the editorial type changes in the original draft document have been deferred to the revised draft.

6.0 SCHEDULE

The work elements described in this plan are not at this time scheduled. No funds are available for these tasks in fiscal year (FY) 98. It is expected that funds will be available in FY99 to implement the additional investigations and finalizing the RFI for SWMU 9. As soon as funding is obtained, a schedule for conducting the work will be prepared and submitted to USEPA for their review and concurrence.

7.0 REFERENCES

Baker Environmental, Inc. (Baker), 1998. Draft RCRA Facility Investigation Report, SWMU 9, Naval Station Roosevelt Roads, Ceiba, Puerto Rico, March, 1998.

Baker, 1997. Final RCRA Facility Investigation Work Plans, Naval Station Roosevelt Roads, Puerto Rico - Addendum 3 - Additional Investigations at SWMU 9. May 15, 1997

Baker, 1996. Draft RCRA Facility Investigation Report for Operable Unit 2, Naval Station Roosevelt Roads, Ceiba, Puerto Rico. September, 1996.

Baker, 1995. Final RCRA Facility Investigation, Naval Station Roosevelt Roads, Puerto Rico, September 14, 1995.

U. S. Environmental Protection Agency, (USEPA) Region 4, 1995. Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment, November, 1995.

U. S. Army Edgewood Research et al., 1996 - Tri-Service Procedural Guidelines for Ecological Risk Assessment, 1996.

USEPA, 1998. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, 1998.

TABLES

TABLE 3-1

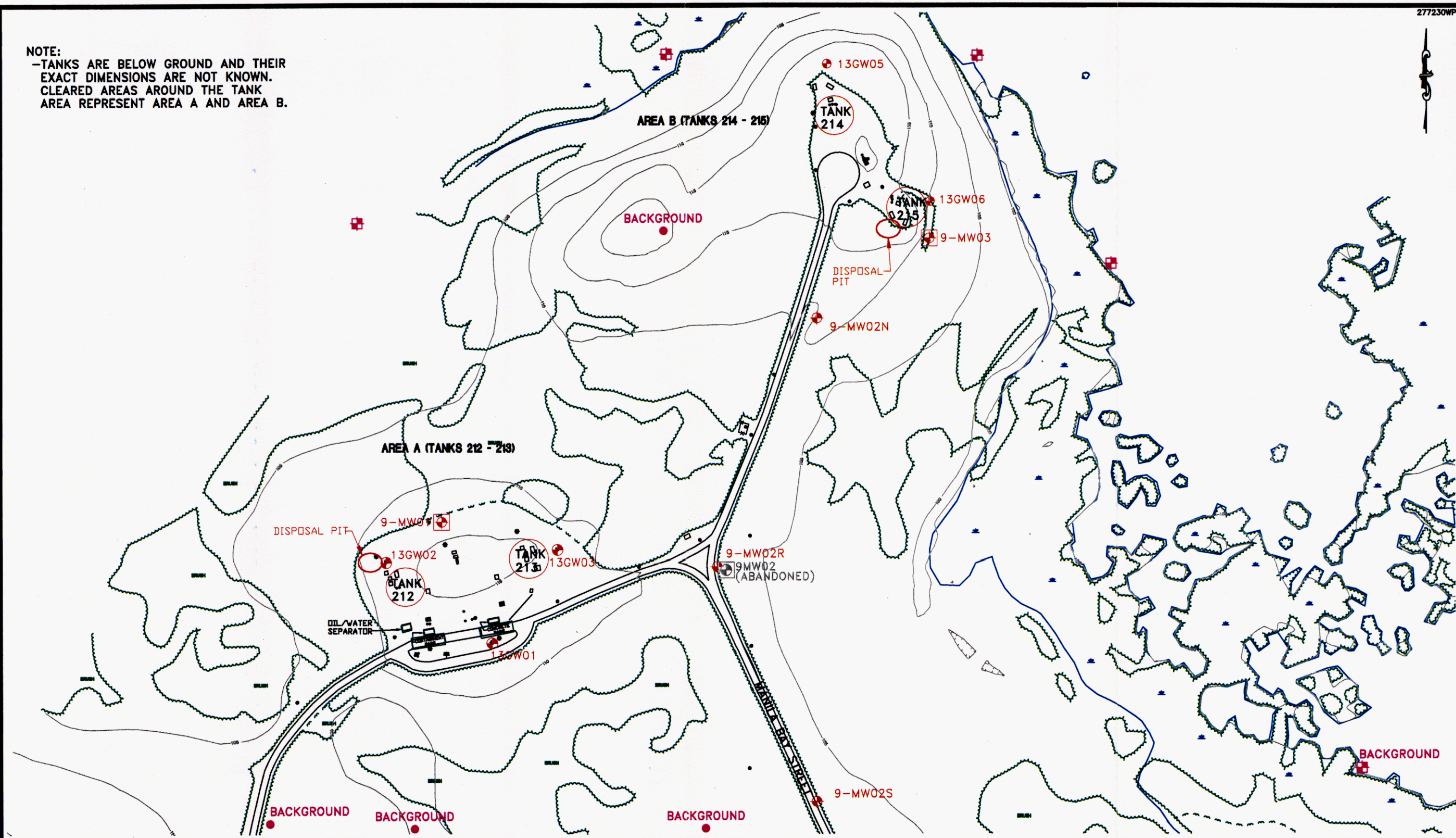
SAMPLING AND ANALYSIS SUMMARY

SWMU 9 - PHASE III INVESTIGATIONS

[illegible]

FIGURES

NOTE:
-TANKS ARE BELOW GROUND AND THEIR
EXACT DIMENSIONS ARE NOT KNOWN.
CLEARED AREAS AROUND THE TANK
AREA REPRESENT AREA A AND AREA B.



- LEGEND**
- MONITORING WELL LOCATION (PHASE II)
 - MONITORING WELL LOCATION (PHASE I)
 - SURFACE ELEVATION CONTOUR
 - APPROXIMATE LOCATION OF DISPOSAL PIT
 - BACKGROUND SOIL AND GROUNDWATER SAMPLING LOCATION
 - SEDIMENT AND SURFACE WATER SAMPLING LOCATION

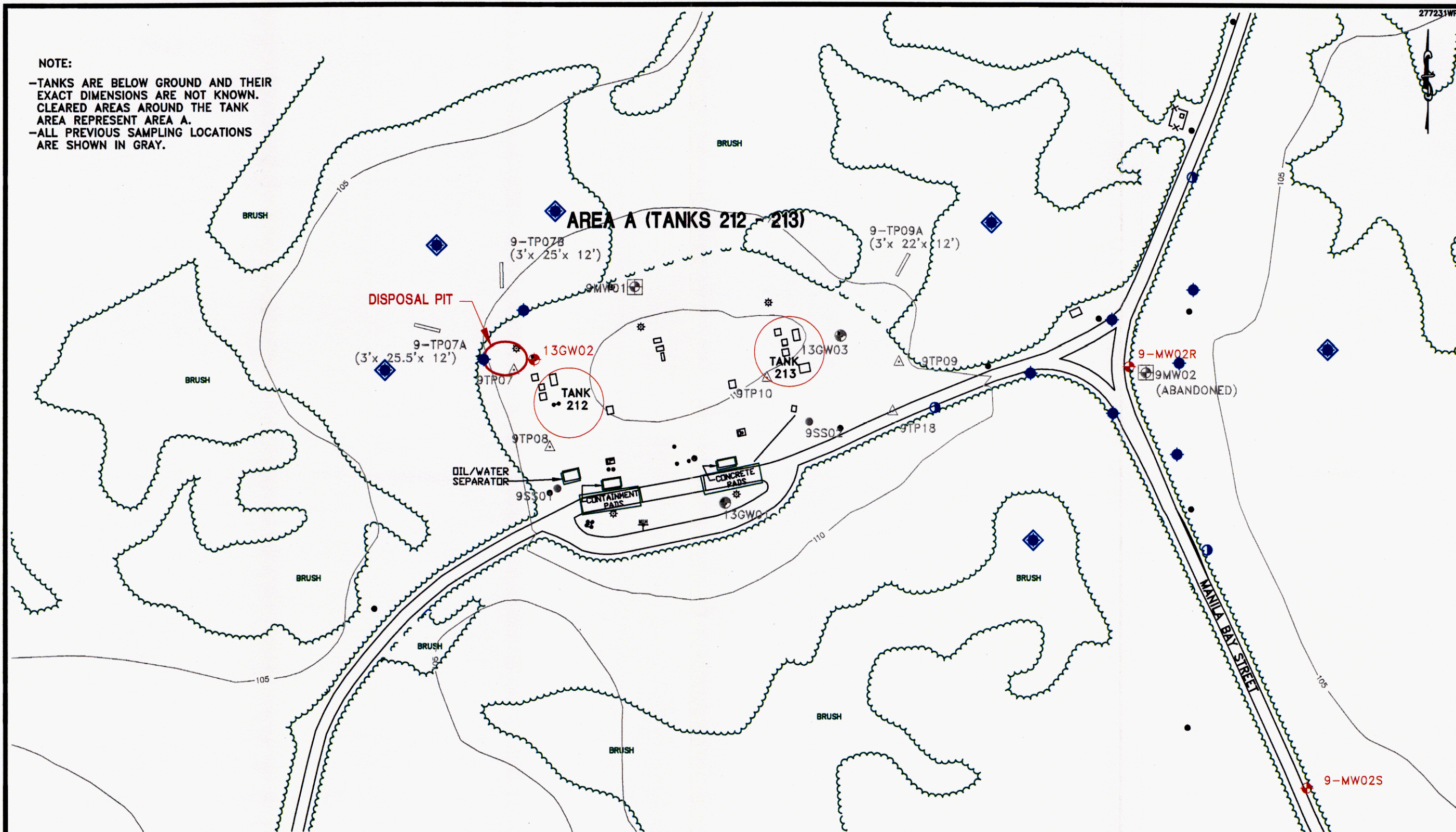
180 0 90 180
1 inch = 180 ft.

Baker

FIGURE 3-1
BACKGROUND AND SEDIMENT/SURFACE WATER SAMPLING LOCATIONS
SWMU 9 - AREAS A AND B
TANKS 212 - 215
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

NOTE:

- TANKS ARE BELOW GROUND AND THEIR EXACT DIMENSIONS ARE NOT KNOWN. CLEARED AREAS AROUND THE TANK AREA REPRESENT AREA A.
- ALL PREVIOUS SAMPLING LOCATIONS ARE SHOWN IN GRAY.



LEGEND

- MONITORING WELL LOCATION (PHASE II)
- TEST PIT LOCATION (PHASE II)
- SURFACE ELEVATION CONTOUR
- APPROXIMATE LOCATION OF DISPOSAL PIT
- HYDROPUNCH PIEZOMETER LOCATION
- HYDROPUNCH LOCATION
- PROVISIONAL SAMPLING LOCATIONS

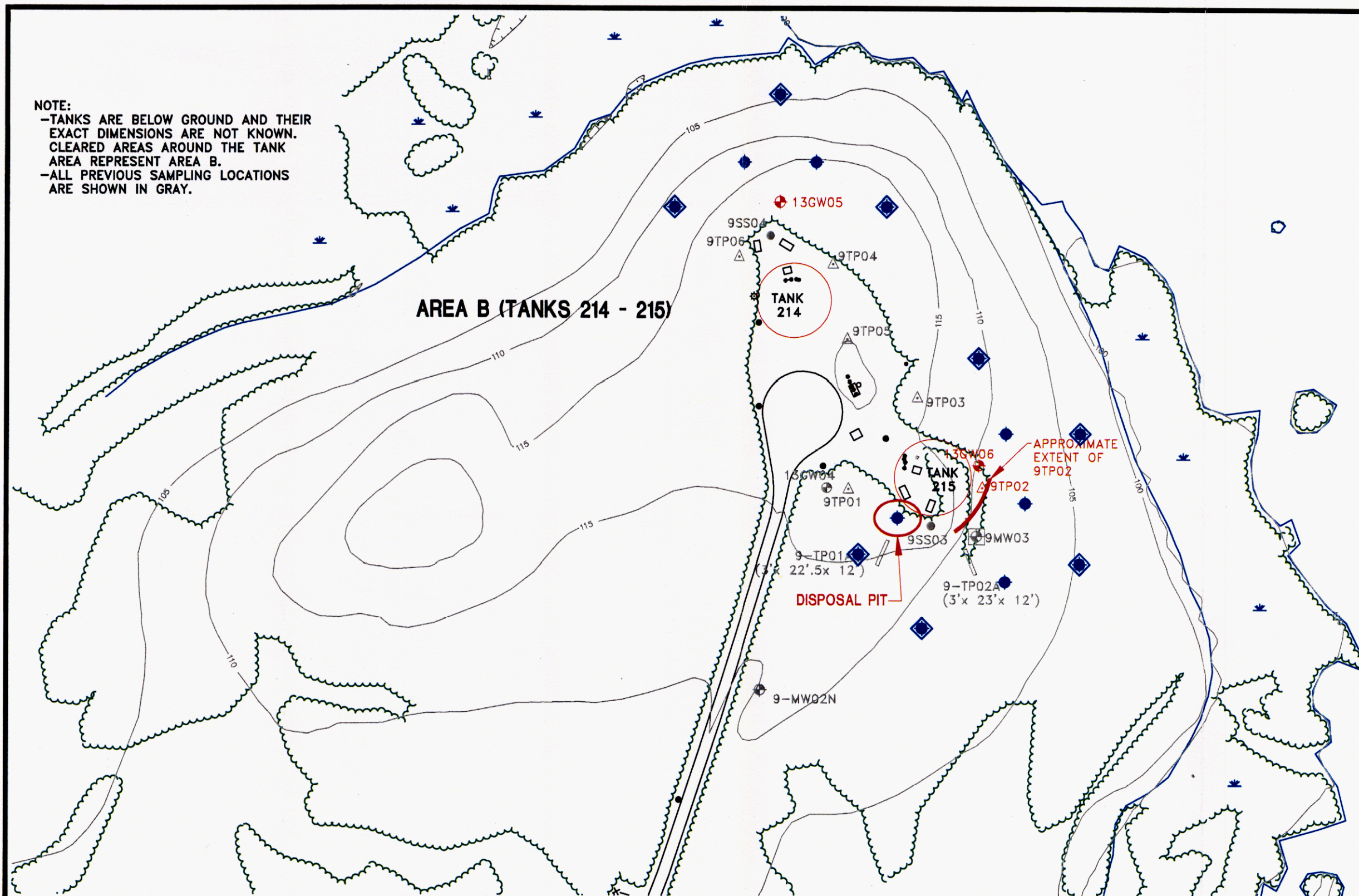
100 0 50 100
1 inch = 100 ft.

Baker

FIGURE 3-2
SAMPLING LOCATIONS - PHASE III
SWMU 9 - AREA A
TANKS 212 - 213
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

NOTE:

- TANKS ARE BELOW GROUND AND THEIR EXACT DIMENSIONS ARE NOT KNOWN. CLEARED AREAS AROUND THE TANK AREA REPRESENT AREA B.
- ALL PREVIOUS SAMPLING LOCATIONS ARE SHOWN IN GRAY.



LEGEND

- EXISTING MONITORING WELL LOCATION
- MONITORING WELL LOCATION (PHASE I)
- MONITORING WELL LOCATION (PHASE II)
- TEST PIT LOCATION (PHASE II)
- SURFACE ELEVATION CONTOUR
- APPROXIMATE LOCATION OF DISPOSAL PIT
- HYDROPUNCH LOCATION
- PROVISIONAL SAMPLING LOCATIONS

100 0 50 100
1 inch = 100 ft.

Baker

FIGURE 3-3
SAMPLING LOCATIONS - PHASE III
SWMU 9 - AREA B
TANKS 214 - 215
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

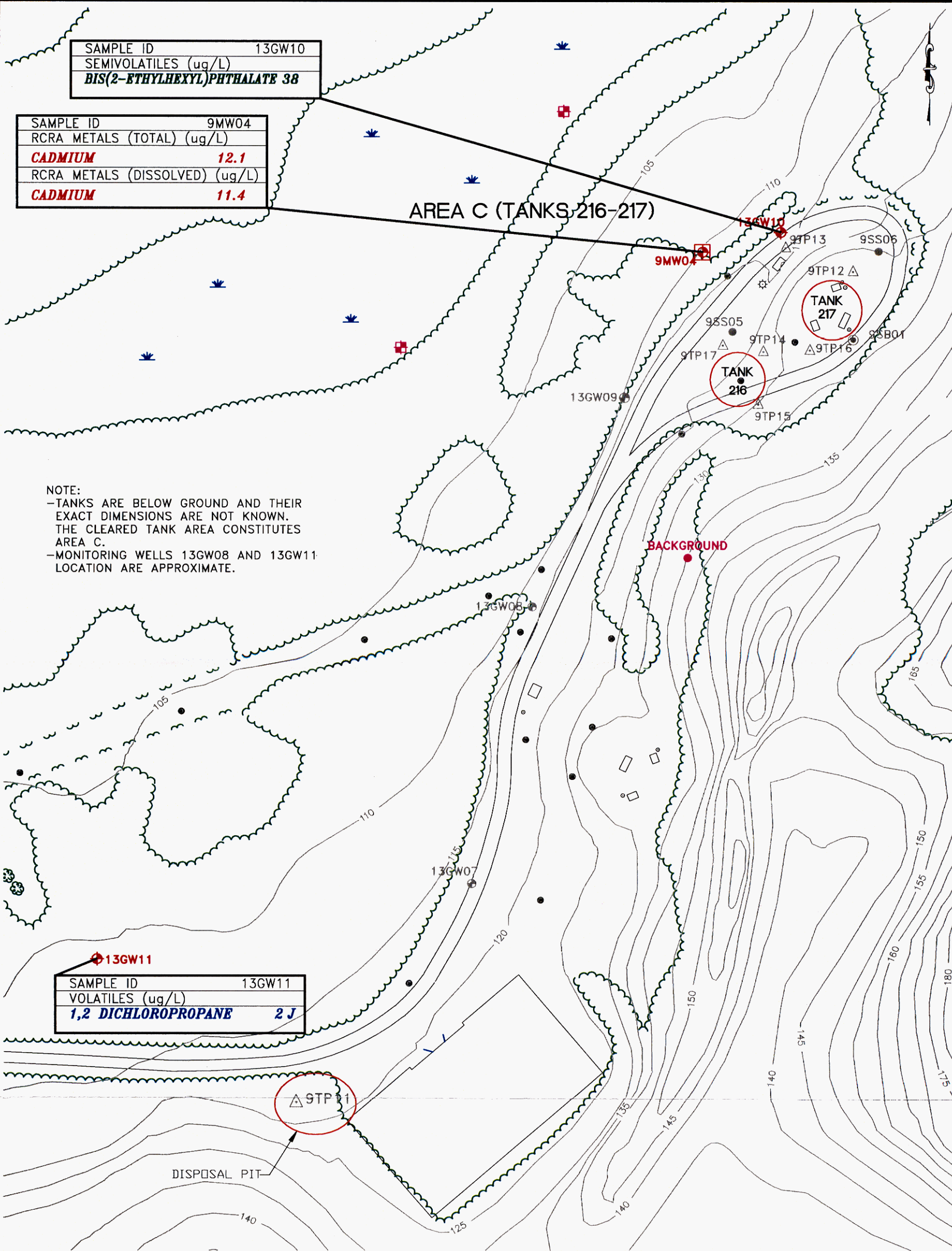
SAMPLE ID	13GW10
SEMIVOLATILES (ug/L)	
BIS(2-ETHYLHEXYL)PHTHALATE 38	

SAMPLE ID	9MW04
RCRA METALS (TOTAL) (ug/L)	
CADMIUM	12.1
RCRA METALS (DISSOLVED) (ug/L)	
CADMIUM	11.4

AREA C (TANKS 216-217)

NOTE:

- TANKS ARE BELOW GROUND AND THEIR EXACT DIMENSIONS ARE NOT KNOWN. THE CLEARED TANK AREA CONSTITUTES AREA C.
- MONITORING WELLS 13GW08 AND 13GW11 LOCATION ARE APPROXIMATE.



SAMPLE ID	13GW11
VOLATILES (ug/L)	
1,2 DICHLOROPROPANE	2 J

- LEGEND**
- ♦ - EXISTING MONITORING WELL LOCATION
 - ⊕ - MONITORING WELL LOCATION (PHASE I)
 - - SOIL BORING LOCATION (PHASE I)
 - - SURFACE SOIL SAMPLING LOCATION (PHASE I)
 - △ - TEST PIT LOCATION (PHASE I)
 - - - SURFACE ELEVATION CONTOUR
 - - APPROXIMATE LOCATION OF DISPOSAL PIT
 - - BACKGROUND SOIL AND GROUNDWATER SAMPLING LOCATION
 - ⊕ - SEDIMENT AND SURFACE WATER SAMPLING LOCATION

EXCEEDS OF MCLs.
EXCEEDS TAP WATER RBC.
EXCEEDS OF MCLs AND TAP WATER RBC.

FIGURE 3-4
SAMPLING LOCATIONS - PHASE III
SWMU 9 - AREA C
TANKS 216 - 217
NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

Baker

APPENDIX A

Naturally Occurring Soil and Groundwater Constituents

natural environmental conditions.

Relatively little is known about the first two types of soil mineral fixation reactions discussed above. However, these are not considered to be extensively occurring reactions. On the other hand, the fixation of elements via incorporation into the structure of soil minerals during mineral precipitation is an extremely important reaction. This chapter will focus on the types and amounts of elements found in soil, how these elements are fixed into mineral structures, and how some remedial actions have utilized element fixation.

ELEMENT CONCENTRATIONS IN SOIL

Eleven of the elements listed in Table 3.1, along with carbon, hydrogen, and oxygen, constitute over 99 percent of the total elemental content of soil: Al, Ca, Fe, K, Mg, Mn, Na, P, S, Si, and Ti. The remaining one percent is comprised of elements known commonly as the "trace elements." The word "trace" identifies the fact that they occur in soil in minute amounts; it has no bearing or relationship to any concentration limit protecting human health or biota.

Table 3.1 lists the mean concentrations, typical ranges, and observed limits of several elements in natural soil (i.e. background concentrations). The total concentration of any element, C_{Total} , in a soil is equal to:

$$C_{Total} = C_{Fixed} + C_{Adsorbed} + C_{Water} \quad (3.1)$$

where:

C_{Fixed} = concentration of fixed element comprising part of the structure of clay and soil minerals, in mg element/kg soil.

$C_{Adsorbed}$ = concentration of element adsorbed onto the surface of soil minerals and onto organic matter exchange sites, in mg element/kg soil.

C_{Water} = concentration of element in soil water or groundwater in equilibrium with $C_{Adsorbed}$, in mg soluble element/kg soil. (See Table 3.2 for natural background levels found in groundwater).

C_{Fixed} represents the "immobile" fraction of C_{Total} . The sum of $C_{Adsorbed}$ and C_{Water} represents the potentially mobile portion of C_{Total} ; these will be discussed in detail in the next chapter.

There are four important facts that should be understood concerning the data listed in Table 3.1, the parameters listed in Equation 3.1, and the interrelationships of these parameters. First, C_{Total} should not be expected to be uniform with depth. Natural processes involved in the distribution of elements in the soil profile include:

TABLE 3.1 Native Soil Concentrations of Various Elements

Element	Concentration (ppm)	
	Typical Range	Extreme Limits
→ Ag	0.1 - 5.0	0.1 - 50
Al	10,000 - 300,000	—
→ As	1.0 - 40	0.1 - 500
B	2.0 - 130	0.1 - 3000
Ba	100 - 3500	10 - 10,000
Be	0.1 - 40	0.1 - 100
Br	1.0 - 10	—
Ca	100 - 400,000	—
→ Cd	0.01 - 7.0	0.01 - 45
Ce	30 - 50	—
Cl	10 - 100	—
Co	1.0 - 40	0.01 - 500
Cr	5.0 - 3000	0.5 - 10,000
Cs	0.3 - 25	—
Cu	2.0 - 100	0.1 - 14,000
F	30 - 300	—
Fe	7,000 - 550,000	—
Ga	0.4 - 300	—
Ge	1.0 - 50	—
→ Hg	0.01 - 0.08	—
I	0.1 - 40	—
K	400 - 30,000	—
La	1.0 - 5000	—
Li	7.0 - 200	1.0 - 3000
Mg	600 - 6000	—
Mn	100 - 4000	1.0 - 70,000
Mo	0.2 - 5.0	0.1 - 400
Na	750 - 7500	400 - 30,000
Ni	5.0 - 1000	0.8 - 6200
P	50 - 5000	—
Pb	2.0 - 200	0.1 - 3000
Ra	10 - 6.5 - 10 - 5.7	—
Rb	20 - 600	3.0 - 3000
S	30 - 10,000	—
→ Sb	0.6 - 10	—
Sc	10 - 25	—
→ Se	0.1 - 2.0	0.01 - 400
Si	230,000 - 350,000	—
Sn	2.0 - 200	0.1 - 700
Sr	50 - 1000	10 - 5000
→ Th	0.1 - 12	—
Ti	1000 - 10,000	400 - > 10,000
U	0.9 - 9.0	< 250
V	20 - 500	1.0 - 1000
Y	10 - 500	—
Zn	10 - 300	3.0 - 10,000
Zr	60 - 2000	10 - 8000

^a Based on an Analysis of Data Presented in References 1,2,3,4,5, and 6.

Materials. Dragan, James, Haradous
Materials Research Institute, 1988

- Leaching of mobilized elements such as calcium, boron, lithium, iron, magnesium, manganese, selenium, or sodium (a) out of the soil profile, or (b) into zones of accumulation.
- Translocation, in the course of soil-forming processes such as podzolization, of trace elements together with iron and aluminum.
- Mobilization of trace elements through breakdown of soil minerals as a result of alternate wetting and drying.
- Mechanical translocation of clay, which increases trace element concentrations in those soil horizons having higher amounts of clay particles.
- Surface accumulation of relatively soluble elements such as boron, calcium, and sodium in arid regions.
- Mobilization or fixation arising from chemical and/or microbiological activity.
- Surface enrichment due to trace element uptake by plants.

Second, analytical data derived from the chemical analysis of the total element content of a soil (i.e. C_{Total}) relays no information regarding C_{Fixed} , C_{Adsorbed} , and C_{Water} other than the magnitude of their combined concentrations. In other words, if a laboratory report states that a soil contains 125 ppm total Cu, this datum cannot reveal if 0.1 percent is potentially mobile (i.e. $C_{\text{Adsorbed}} + C_{\text{Water}}$) or if 99 percent is potentially mobile. At background concentrations, the relative magnitudes of the parameters listed in Equation 3.1 for cations generally are:

$$C_{\text{Fixed}} \gg C_{\text{Adsorbed}} > C_{\text{Water}}$$

The greater part of C_{Total} exists as C_{Fixed} and is immobile. However, this relative ranking may or may not change as C_{Total} increases above the background concentration.

Third, the background concentrations listed in Table 3.1 represent the total concentration of an element present after the soil was formed and weathered. This concentration gives no information on the element-loading capacity of a soil. The element-loading capacity can be defined as the maximum amount of an element that can be added to soil which does not cause water migrating through this soil to contain a harmful concentration of that element. In other words, knowing that a soil contains 125 ppm total background Cu will not reveal if soil will or will not completely convert an additional loading of 500 ppm Cu into C_{Fixed} .

Soil cleanup standards that specify the excavation or treatment of soil containing concentrations of an element over a background concentration are usually based on an incorrect premise that the background concentration of an element in soil represents a maximum concentration of an element which the soil can immobilize. The background concentration represents the total concentration present after the soil was formed and undergone some degree

Element	Concentration	
	Typical Value	Background Value
Major Elements (ppm)		
Ca	1.0 - 150 ^b < 500 ^d	95,000 ^c
Cl	1.0 - 70 ^b < 1000 ^d	200,000 ^c
F	0.1 - 5.0	70 1600 ^c
Fe	0.01 - 10	> 1000 ^c
K	1.0 - 10	25,000 ^c
Mg	1.0 - 50 ^b < 400 ^d	52,000 ^c
Na	0.5 - 120 ^b < 1000 ^d	120,000 ^c
NO ₃	0.2 - 20	70
SiO ₂	5.0 - 100	4,000 ^c
SO ₄	3.0 - 150 ^b < 2000 ^d	200,000 ^c
Sr	0.1 - 4.0	50
Trace Elements (ppb)		
→ Ag	< 5.0	
Al	< 5.0 - 1000	
As	< 1.0 - 30	4,000
B	20 - 1000	5,000
Ba	10 - 500	
Br	< 100 - 2000	
Be	< 10	
Bi	< 20	
→ Cd	< 1.0	
→ Co	< 10	
Cr	< 1.0 - 5.0	
Cu	< 1.0 - 30	
Ga	< 2.0	
Ge	< 20 - 50	
→ Hg	< 1.0	
I	< 1.0 - 1000	48,000 ^c
Li	1.0 - 150	
Mn	< 1.0 - 1000	10,000 ^c
Mo	< 1.0 - 30	10,000
Ni	< 10 - 50	
PO ₄	< 100 - 1000	
→ Pb	< 15	
Ra	< 0.1 - 4.0 ^f	720 ^{c, f}
Rb	< 1.0	
→ Se	< 1.0 - 10	
Sn	< 200	
Ti	< 1.0 - 150	
U	0.1 - 40	
→ V	< 1.0 - 10	70
Zn	< 10 - 2000	
Zr	< 25	

^a based on an analysis of data presented in references 7, 8, and 9.

^b in relatively humid regions.

^c in brine.

^d in relatively dry regions.

^e in thermal springs and mine areas.

^f picocuries/liter (i.e. 0.037 disintegrations/sec).

From: McGraw Hill Encyclopedia of the Geological Sciences. Gilbert and Kelein, et al. McGraw Hill, 1989.

Powder River is derived from many stream sources, and excess molybdenum that any one stream may contribute is largely diluted.

Magnesium. Studies of magnesium concentration in grasses reveal how glaciers, overriding bedrock, influence glacial drift and the soils formed on it. There is appreciably more magnesium in grasses from the glacial drift plains in Wisconsin than in similar grasses from the drift plains in Michigan. The soils in the two states are morphologically and genetically the same, and differ principally in the underlying limestone bedrock that the glaciers overrode. Dolomite is a magnesium-rich limestone that underlies areas in Wisconsin but not Michigan. The southerly movement of the glaciers has expanded the influence of the dolomitic rock into parts of Illinois and Iowa.

Grass tetany is a nutritional deficiency disease due to low magnesium in forage plants. Grasses with 0.2% magnesium or more protect cattle from grass tetany. The disease is virtually absent in Wisconsin but quite prevalent in Michigan.

Pregnant cows and cows with nursing calves are most susceptible to grass tetany. Older cows in the fourth or fifth pregnancy are more susceptible than younger ones. Knowing the geographic areas where cows may graze low-magnesium forage is important so that animal losses can be minimized, especially in springtime when the incidence of grass tetany is highest. Cool-season grasses are often the first fresh forage available to cattle in spring. If the growing temperature during this period is warm, grasses tend to have more magnesium. However, soils formed in dolomitic till tend to overcome effects of cool temperature and grow grasses with magnesium adequate for animals. In the West, grasses growing on soils formed in or influenced by volcanic ash generally have small amounts of magnesium and respond only weakly to warm growing temperatures. In these soils, the grasses have 0.15% or less of magnesium.

Selenium. Other mineral elements are associated with soil-related nutritional problems in animals as a result of soil parent material interacting with soils. The best-known disease is selenium toxicity, or selenosis. In parts of the Rocky Mountain and the Great Plains states where calcareous soils are formed in seleniferous rocks, or in materials derived from them, the incidence of selenosis in grazing animals is high. Acute cases occur where selenium accumulator plants such as *Astragalus bisulcatus* or *Stanleya pinnata* grow. These plants may have a selenium level of 1000 ppm or more, often greatly exceeding the level in the soil. Selenium-rich rocks occur in Hawaii and Puerto Rico, but selenosis is not a nutritional problem there. Selenium is appreciably less available to plants growing on acid soils, and the plants do not accumulate levels toxic to animals. Because of the differences in plant response, the selenium-rich soil areas in Hawaii and Puerto Rico are identified as nontoxic seleniferous soils.

Cobalt. Areas of cobalt deficiency in cattle in the eastern United States also result from the combined effect of soil parent materials and the soils themselves. The area between the Merrimac River in New Hampshire and the Saco River in Maine is low in cobalt, because only small amounts were contributed to the glacial drift by the White Mountain granites. The Lower Atlantic Coastal Plain is the other broad area of low-cobalt soils. The coastal plain deposits in which soils formed are materials that already had undergone a cycle of weathering in the uplands. In both

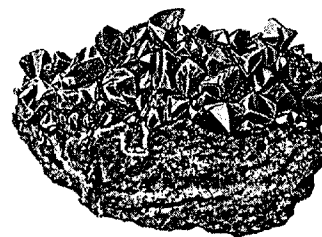
the Northeast and the Southeast, leaching losses of cobalt below rooting depths of common plants occur with the development of Spodosols that form in the sandy deposits. Forage plants and native grasses grown on soils in both areas have 0.04 to 0.07 ppm or less of cobalt, well in the deficiency range recognized for animals.

Joe Kubota

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Sphalerite

A mineral, β -ZnS, also called blende. It is the low-temperature form and more common polymorph of ZnS. Pure β -ZnS on heating inverts to wurtzite, α -ZnS, at 1020°C (1868°F), but this temperature can be lowered substantially by impurity-atom solid solution (especially Cd^{2+} and Fe^{2+}) and sulfur fugacity. Sphalerite crystallizes in the hextetrahedral class of the isometric system with a structure similar to that of diamond. The space group is $F\bar{4}3m$, and the cubic unit cell has an edge $a = 0.543$ nanometer, which contains four ZnS molecules. Zinc atoms occupy the positions of half the carbon atoms of diamond, and sulfur atoms occupy the other half. Each zinc atom is bonded to four sulfur atoms, and each sulfur atom is bonded to four zinc atoms. The common crystal forms of sphalerite are the tetrahedron, dodecahedron, and cube, but crystals are frequently complex and twinned (see *illus.*). The mineral is most commonly in coarse to fine, granular, cleavable masses. The luster is resinous to submetallic; the color is white when pure, but is commonly yellow, brown, or black, darkening with increased percentage of iron. It has been shown that excess sulfur can also contribute to the darkening of the color. There is perfect dodecahedral



(a)



(b)

Sphalerite. (a) Crystals in limestone from Joplin, Missouri (specimen from Department of Geology, Bryn Mawr College). (b) Crystal habit (after C. S. Hurlbut, Jr., *Dana's Manual of Mineralogy*, 17th ed., John Wiley and Sons 1959)

Table 1. Average percentages of the major and some micro elements in subsurface soil clays and crustal rocks

Soil order:	Alfisol	Inceptisol	Mollisol	Oxisol	Spodosol	Ultisol	Crustal rocks
Silicon (Si)	19.20	24.69	23.01	12.43	5.79	16.02	27.72
Aluminum (Al)	12.38	19.61	10.29	19.33	15.86	17.49	8.13
Iron (Fe)	8.04	3.81	6.83	10.83	3.29	11.96	5.00
Calcium (Ca)	0.69	0.00	3.59	0.10	0.29	0.15	3.63
Magnesium (Mg)	1.26	0.40	1.62	0.46	0.15	0.08	2.09
Sodium (Na)	0.18	2.52	0.04	0.00	0.27	0.06	2.83
Potassium (K)	3.63	n.d.	1.20	0.07	0.40	0.22	2.59
Titanium (Ti)	0.40	0.28	0.44	1.32	0.16	0.50	0.44
Manganese (Mn)	0.06	n.d.	0.06	0.08	0.06	0.05	0.10
Phosphorus (P)	0.14	n.d.	0.14	0.27	0.17	0.12	0.11

they are inherited from parent rock or are produced by chemical weathering, respectively.

Primary minerals in soil. The bulk of the primary minerals that occur in soil are found in the silicate minerals, such as the olivines, garnets, pyroxenes, amphiboles, micas, feldspars, and quartz. The feldspars, micas, amphiboles, and pyroxenes commonly are hosts for trace elements that may be released slowly into the soil solution as weathering of these minerals continues. Chemical weathering of the silicate minerals is responsible for producing the most important secondary minerals in soil. The general scheme of the weathering sequence is shown in Fig. 1. *SEE SILICATE MINERALS.*

Secondary minerals in soil. The important secondary minerals that occur in soil are found in the clay fraction. These include aluminum and iron hydrous oxides (sometimes in the form of coatings on other minerals), carbonates, and aluminosilicates. The term allophane is applied to x-ray amorphous, hydrous aluminosilicates that are characterized by variable composition and a defect-riddled kaolinite structure containing Al in both tetrahedral and octahedral coordination. The significant crystalline aluminosilicates possess a layer structure; they are chlorite, halloysite, kaolinite, montmorillonite (smectite), and vermiculite. These clay minerals are identified in soil by means of the characteristic x-ray diffraction patterns they produce after certain pretreatments, although their positive identification may be difficult if two or more of the minerals are present at once. *SEE CLAY MINERALS.*

The distribution of secondary minerals varies among different soils and changes with depth below

the surface of a given soil. However, under a leaching, well-oxidized environment, soil minerals do possess a differential susceptibility to decomposition, transformation, and disappearance from a soil profile. This has made possible the arrangement of the clay-sized soil minerals in the order of increasing resistance to chemical weathering. Those minerals ranked near the top of the following list are present, therefore, in the clay fractions of slightly weathered soils; those minerals near the bottom of the list predominate in extensively weathered soils.

Weathering index	Clay-sized minerals
1	Gypsum, halite
2	Calcite, apatite
3	Olivine, pyroxene
4	Biotite, mafic chlorite
5	Albite, microcline
6	Quartz
7	Muscovite, illite, sericite
8	Vermiculite
9	Montmorillonite, Al-chlorite
10	Kaolinite, allophane
11	Gibbsite, boehmite
12	Hematite, goethite
13	Anatase, rutile, zircon

In zonal soils of humid-cool to subhumid-temperate regions, illite is the predominant clay mineral. Mixtures of kaolinite, vermiculite, and interstratified clay minerals are found in humid-temperate regions. In humid-warm regions, kaolinite, halloysite, allophane, gibbsite, and goethite are found. The mineralogical composition of the highly weathered and leached soils of the humid tropics is a subject of active investigation, in part because these soils (the Oxisols and Ultisols) constitute approximately one-third of the world's potentially arable land. The soil minerals are dominated by iron and aluminum hydrous oxides, kaolinite, halloysite, and quartz. Weathering residues also are found in thin coatings on clay particle surfaces. Vermiculite and montmorillonite with interlayer Al hydroxy polymers are common.

The chemical conditions favoring the genesis of kaolinite are the removal of the basic cations and Fe^{2+} by leaching, the addition of H^+ in fresh water, and a high Al-Si molar ratio. Smectite (montmorillonite) is favored by the retention of basic cations (arid conditions or poor drainage) and of silica. *SEE GIBBSITE; GOETHITE; HALLOYSITE; ILLITE; KAOLINITE; MONTMORILLONITE; VERMICULITE.*

Table 2. Average amounts of trace elements commonly found in soils and crustal rocks

Trace element	Soil, mg/kg	Crustal rocks, mg/kg
Arsenic (As)	6	1.8
Boron (B)	10	10
Cadmium (Cd)	0.06	0.2
Columbium (Co)	8	25
Chromium (Cr)	100	100
Copper (Cu)	20	55
Molybdenum (Mo)	2	1.5
Nickel (Ni)	40	75
Lead (Pb)	10	13
Selenium (Se)	0.2	0.05
Vanadium (V)	100	135
Zinc (Zn)	50	70

From: McGraw Hill Encyclopedia of the Geological Sciences. Gilbert and Klein, et al. McGraw Hill, 1987

APPENDIX B
EPA Region III
Biological Technical Assistance Group
Ecological Screening Criteria

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
841 Chestnut Building
Philadelphia, Pennsylvania 19107

SUBJECT: Revised Region III BTAG Screening
Levels

DATE: 8-9-95

FROM: Robert S. Davis, *RGD* Biologist (3HW13)
Technical Support Section

TO: Users

Attached is a revised version of the screening tables initiated last year. It is changed substantially for several contaminants and also now includes citations placing it on sounder ground than before. While it is still very conservative, it can serve as a basis for risk assessments and can also find use in discussions during scoping for the RI/FS process.

If you have any questions, please feel free to contact me.

BTAG SCREENING LEVELS

SUGGESTED USE OF THESE TABLES

The objective of the attached tables is to provide a set of conservative guidelines for the evaluation of sampling data at Superfund sites. They should be used in developing screening level risk assessments in cases where insufficient information has been gathered to warrant a more rigorous assessment. The more rigorous assessment can be carried out when an appropriate quantity and quality of data have been collected.

The numbers in the tables are based upon the lowest value from a combination of sources considered to be protective of the most sensitive organism in a medium. The sources are peer reviewed literature, regulatory agency criteria, and technical experts from federal agencies (e.g., Eisler, R. "Contaminant Hazard Reviews", FWS). The media are the basic units of the habitat and are considered to be fundamental to the well-being of the endemic ecological populations.

Often too little data are gathered at Superfund sites to determine a potential for risk to endemic populations at a given site, as identified through the ecological characterization. In the absence of this, the risk assessor can decide to use either models and extrapolations from the literature or a site-specific and conservative risk assessment. These tables are meant to serve as a basis for the latter. The use of models and extrapolation is not encouraged due to limitations of assumptions and on-site verification and validation.

Characterization of the media should provide sufficient information for use by the risk assessor in developing the assessment. For example, at a site that is paved or otherwise covered and where soil samples show a high potential for risk, the risk assessor's judgement should play the major role. In such a case (described in the risk assessment site conceptual model), it would be assumed that the contamination is likely to be isolated from the ecological receptors. It would be obvious that the potential for risk is strongly mitigated by site conditions.

Another case may be in areas of high clay of the northeastern US where aluminum, iron, and magnesium are generally found at rather high levels. Aluminum may be at injurious levels, according to the tables. Where these three metals are identified, the risk assessor can often use his judgement and eliminate them from consideration in the assessment. In this case, aluminum would be regarded as an artifact of soil.

On the other hand, aluminum could still be a contami-

nant of concern if it is released from soils as a result of physical disturbance or chemical contamination. For example, a spill of highly concentrated acid could conceivably cause the soil to release high quantities of aluminum. In such cases, aluminum may, in the judgement of the risk assessor, be a contaminant of concern.

In sum, site-specific information and conditions may vary, dictating adjustment of the criteria used in the risk assessment, but the values in the table can be used as a starting point for any ecological risk assessment.

Region III BTA Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment		BCF
	Marine		Fresh				data for Effects Range-Low, unless otherwise noted		
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
INORGANICS									
Aluminum			460.0 (pH, a) ^{*1}	25.0 (pH) ^{*2} (c)	1000.0 ³				231(F) [*]
Ammonia	39.0 (a)	17.0 (c)		17.0 (c)					
Antimony		500.0(p,c) ⁴		30.0 (p,c) ⁵	480.0			150,000 (AET) ⁶	
Arsenic (total)				874.0 (c) ⁷	328 ppm ⁸			8,200.0 ⁹	
Ar ⁺³	19.0 (c)	36.0 (c) ¹⁰		190.0 (c) ¹¹				57.0 (AET) ^{12*}	3(I) [*] ; 4(F) [*]
Ar ⁺⁵	13.0 (c)	10 ¹³	48.0 (a) ¹⁴						3(I) [*] ; 3(F) [*]
Barium	10,000.0 (a)				440,000.0 ¹⁵				17,000(Pl) [*] ; 900(I) [*] ; 8(F) [*]
Beryllium		1500 ¹⁶		5.3 (h,c) ^{*17}	20.0 (pH) [*]				19(F) [*] ; 100(I,Pl) [*]
Boron		12,000.0 (a) ¹⁸	75,000.0 (pH, c) [*]	53,000.0 (c)	0.5				4(Pl) [*] ; 198(F) [*]
Cadmium		9.3 (h,c) ^{*19}	1.1 (h,c) [*]	0.53 (h,c) ^{*20}	2,500.0 ²¹		5.1 mg/kg	1200.0 ²²	10,000(I) [*] ; 4,900(F) [*]
Chromium (total)					20.0 ²³	7.5 ²⁴	5.0 ²⁵	260.0 mg/kg(AET) [*]	1,000,000(I) [*] ; 1,000(Pl) [*]
Cr ⁺³	10,300.0 (a) ²⁶		120.0 (h,c) ^{*27}				<81,000.0 ²⁸		192(I) ^{29*}
Cr ⁺⁶	50.0 (c) ³⁰		2.0 (c)	11.0 (c) ³¹			< 81,000.0 ³²		3.4(F) [*] ; 192(I) ^{*33}
Cobalt				35,000.0 ³⁴ (c)	100.0 ppm (pH) ^{35*}	200.0 ppm ³⁶			40(F) [*]
Copper		2.9 (a) ³⁷		6.5 (c) ^{*38}	15,000 ³⁹			34,000.0 ^{40*}	51.20(23.53 ⁴¹)(Pl) [*] ; 0(F) [*]
Cyanide	1.0(a) ⁴²		5.2(c) ⁴³			>5.0 ⁴⁴			

a - acute; c - chronic; p - proposed; * - (h) - value is dependant on hardness; (pH) - value is dependant on pH; F - fish; I - invertebrate; Pl - plant; AET - Apparent Effect Threshold

If unmarked, put with acute

Region III BTAG Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment		BCF
	Marine		Fresh				data for Effects Range-Low, unless otherwise noted		
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
Fluorides			2,000.0 (a) ⁴⁵	2,700.0 (a) ⁴⁶	1000.0 ⁴⁷				significant bioaccumulation is noted in aquatic species
Iron				320.0 (cI), 900.0(cF)	3,260,000 ⁴⁸	12 mg/kg ⁴⁹			
Lead ⁵⁰	5.1 (pH, h, c) [*]	5.6(c) ⁵¹		3.2 ⁵² (pH, h, c) [*]	2,000.0 ⁵³	10.0 ⁵⁴		46,700.0 ⁵⁵	17.5(I) ^{*56} ; 726(F) [*]
Magnesium						0.44%			
Manganese	200.0 (pH, h, c) [*]	10.0 (pH, h, c) [*]		14.5 mg/L (pH, h, c) ^{*57}		330,000.0			35(F) [*] ; 300(PI) [*]
Mercury ⁵⁸	0.025 (pH, h, c) ^{*59}		0.012 (pH, h, c) ^{*60}		58.0		150.0 ⁶¹		23,661(I) [*] ; 7,000(F) [*]
Molybdenum					590.0				
Nickel	8.3 (h,c) ^{*62}		340.0 ^{*63}	160.0 (h,c) ^{*64}	2,000.0 ⁶⁵		20,900.0 ⁶⁶		40,000(PI) [*] ; 100(F) [*]
Phosphorus	0.1 (c) ⁶⁷			0.1 (c) ⁶⁸					2,000(F) [*]
Selenium		35.0 ⁶⁹ (c)	522.0 (a)	5.0 ⁷⁰ (c)	1800.0 ⁷¹				28,870(I) [*] ; 470(F) [*]
Silver	1.9 (a) [*]	0.0001 (c) [*]	1.9 (a) [*]	0.0001 (h,c) [*]	0.0098 ⁷²			1000.0 ^{*73}	34,000(PI) ^{*74} ; 150(F) [*]
Strontium					120,000.0				
Thallium		2130.0 (a) ⁷⁵		40.0 (c) ⁷⁶	1.0				130(F) [*] ; 18(I) [*]
Tin		.01 (c) ⁷⁷		.026(c) ⁷⁸	890.0				high bioaccumulation has been noted
Uranium					2,300.0				
Vanadium		< 10.0 mg/L		< 10.0 mg/L	500 ⁷⁹	58,000.0			
Zinc	19.0 (c)	86.0 (c) ⁸⁰	30.0 (h,c) [*]	110.0 (h,c) ^{*81}	10,000.0 ⁸²			150,000.0 ⁸³	50,000(PI) ^{*84} ; 100,000(I) [*] ; 2,000(I) [*]

Endnotes - Inorganics

1. Green alga, Selenastrum capricornutum; chronic AWQC are pH dependent
2. Reference #8, Leino.
3. Reference #4, OHMTADS.
4. Reference #5, IRIS.
5. Reference #5, IRIS.
6. Reference #1, NOAA.
7. Gammarus pseudolimnaeus
8. Reference #4, OHMTADS.
9. Reference #2, E.R. Long.
10. Reference #5, IRIS.
11. Reference #5, IRIS.
12. AET values for arsenic are 57, 93 and 700 mg/kg (dry wt) for amphipods, oysters and benthic organisms respectively.
13. Reference #4, OHMTADS.
14. EC₅₀ data for Scenedesmus obliquus
15. Reference #1, NOAA.
16. Reference #4, OHMTADS.
17. Reference #5, IRIS.
18. Coho salmon, Oncorhynchus kisutch
19. Reference #5, IRIS.
20. LC₅₀ mortality for Hyalella azteca, scud; reference #10, Borgmann.
21. Reference #4, OHMTADS.
22. Reference #2, E.R. Long.
23. Greatest (Cr) toxicity risk to plants is posed in acidic sandy soil with low organic content
24. Gram negative bacteria, including Pseudomonas and Nocardia

25. Tobacco, Nicotiana tabacum
26. Reference #5, IRIS.
27. Reference #5, IRIS.
28. Reference #2, E.R. Long.
29. Reference #6, USEPA.
30. Reference #5, IRIS.
31. Reference #5, IRIS.
32. Reference #2, E.R. Long.
33. Reference #6, USEPA.
34. 100% mortality for Rainbow trout; reference #11, Schweiger.
35. Reference #7, Parr.
36. Animal health is affected by plants containing 100 ppm cobalt, therefore loading rates should be based on soil concentrations which produce plants with cobalt concentrations less than 100 ppm. A conservative value for cumulative cobalt of 200 ppm in the soil is suggested to immobilize the element as well as to avoid excessive plant uptake.
37. Pacific oyster (embryo); reference #5, IRIS.
38. EC₅₀ for Daphnia magna; reference #5, IRIS.
39. Reference #4, OHMTADS.
40. Reference #2, E.R. Long.
41. Value obtained when iron was added to the test solution at equal concentrations with copper
42. Reference #5, IRIS.
43. Reference #9, Smith, Jr., Lloyd.
44. > 5.0 is lethal to soil amoeba; Reference #4, OHMTADS.
45. 35% growth reduction observed after a 48 hr period
46. 48-hr LC₅₀ for rainbow trout, Salmo gairdneri
47. Reference #4, OHMTADS.
48. Reference #4, OHMTADS.
49. LD₅₀ for rabbits.

50. For all species, lead toxic effects were most pronounced at elevated water temp. and reduced pH, in soft water, in younger life stages, and after long exposure.
51. Reference #5, IRIS.
52. An acute value of 3.5 ug/L tetramethyl lead is reported for rainbow trout Salmo gairdneri. Reference #5, IRIS.
53. Reference #5, OHMTADS.
54. Japanese quail show extreme sensitivity, with a significant reduction in both calcium and egg production
55. Reference #2, E.R. Long.
56. Value for marine (freshwater value is 1000)
57. The 96-hour LC_{50} for rainbow trout in soft water (hardness = 36 mg/L) was 14.5 mg/L.
58. Alkalinity, water hardness, ascorbic acid, chloride, dissolved oxygen, pH, organic complexing agents, sediment and temperature all affect toxicity
59. Reference #5, IRIS.
60. Reference #5, IRIS.
61. Reference #2, E.R. Long.
62. Reference #5, IRIS.
63. EC_{50} of 340 ug/L was reported for duckweed, Lemna minor.
64. Reference #5, IRIS.
65. Various fungi (e.g. P canescens, P rubrum, R arrhizus, and T polysporum) are inhibited at this level; Reference #4, OHMTADS.
66. Reference #2, E.R. Long.
67. Reference #5, IRIS.
68. 96-hr LD_{50} for bluegills. Reference #5, IRIS.
69. Harmful effects on fish fry
70. Reference #5, IRIS.
71. Reference #4, OHMTADS.
72. Corn
73. Reference #2, E.R. Long.
74. Data for the diatom, Thalassiosira pseudonans, exposed to silver cyanide
75. Reference #5, IRIS.

76. Reference #5, IRIS.
77. Reference #5, IRIS.
78. Reference #5, IRIS.
79. Reference #4, OHMTADS.
80. Reference #5, IRIS.
81. Reference #5, IRIS.
82. Reference #4, OHMTADS.
83. Reference #2, E.R. Long.
84. Alga, Nitzshia sp.

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1. NOAA Screening Guidelines for Inorganics. Hazmat Report 94-8.
 2. HSDB (through February 1995). Hazardous Substance Data Base. National Library of Medicine, National Toxicology Information Program, Bethesda MD. June 12, 1995.
 3. Long, Edward R. et al, Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments; *Environmental Management* Vol. 19, No. 1, pp 81-97. 1995 Springer-Verlag New York Inc.
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 5. IRIS (through May 1995). Integrated Risk Information System (database). Ambient Water Quality Criteria, Aquatic Organisms. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, OH. July 19, 1995.
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Region III B' Screening Levels

(all values in $\mu\text{g/g}$, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment data for Effects Range- Low, unless otherwise noted		BCF
	Marine		Fresh						
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
CHLORINATED DIOXINS & PCBS									
2,3,7,8-TCDD			< 0.00001 (c) ¹			10.0 ²			29,200(F)
Polychlorinated Biphenyls (PCBs)	0.03 (c) ³		0.1 (a)	0.014 (c) ⁴	100.0(Pl)		22.7 ⁵		340,000(I) ⁶ ; 270,000(F) ^{6*}
SEMI-VOLATILES									
Benzidine			2,500.0 (a) ⁷						44(F), 456(I)
Benzoic Acid							650.0 (AET) ^{*8}		14(F), 1800(I) ⁹
Benzyl Alcohol				460 mg/L ¹⁰			57.0 (AET) ^{*11}		
4-Chloroaniline	29,700.0 (a) ¹²								
Dibenzofuran							540.0 (AET) ^{*13}		82(I) 947(F)
1,2-Diphenylhydrazine			270.0 (a) ¹⁴						
2-Hexanone				428,000.0 (a) ¹⁵					6
Isophorone	12,900.0 (a) ¹⁶		117,000.0 (a) ¹⁷						7(F) ¹⁸
Methyl Ethyl Ketone (MEK)				3,220,000.0 (a) ¹⁹					significant bioaccumulation expected
Methyl Isobutyl Ketone (MIBK)				460,000.0 (a) ²⁰		100,000.0 ²¹			5(estimated)
Thiodiglycol			1.1 X 10 ¹¹ (a)	684,300.0 (a) ²²					
SEMI-VOLATILE - NITROAROMATICS									
2,4-Dinitrotoluene	370.0 (c) ²³		230.0 (c) ²⁴						
Nitrobenzene	6,680.0 (a) ²⁵		27,000.0 (a) ²⁶						
N-Nitrosodiphenylamine	3.3 X 10 ⁶ (a) ²⁷		5,850.0 (a) ²⁸				28.0 (AET) ^{*29}		
SEMI-VOLATILE - ORGANOHALIDES									
Aldrin	1.3 (a) ³⁰		3.0 (a) ³¹		<100.0				

Region III BTA Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment		BCF
	Marine		Fresh				data for Effects Range-Low, unless otherwise noted		
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
Bromochloromethane		6,400 (c) ³²		11,000 (a) ³³		3.0 X 10 ⁶ ³⁴			7(estimated)
Bromodichloromethane		6,400 (a) ³⁵		11,000 (a) ³⁶		450.0 mg/kg ³⁷			1.37
Chlordane		0.004 (c) ³⁸		0.0043 (c) ³⁹		< 100.0			
2-Chloronaphthalene		7.5 (a) ⁴⁰		620 (c) ⁴¹					
DDD		0.68 (a) ⁴²		0.6 (a)		< 100.0		<16 (AET) ⁴³	47,900(I)*; 6,210(PI)*; 52,500(F)
DDE		14.0 (a) ⁴⁴		1,050.0 (a) ⁴⁵		< 100.0		2.2 ⁴⁶	59,000(I)*; 10,000(PI)*; 81,000(F)
DDT	5,000.0 (a)	0.001 (c) ⁴⁷	5,000.0 (a)	0.001 (c) ⁴⁸		<100.0 ⁴⁹		1.58 ⁵⁰	100,000(F)*; 690,000(I)*; 21,580(PI)
1,2-Dibromo-3-Chloropropane									11(estimated)
Dieldrin		0.0019 (c) ⁵¹		0.0019 (c) ⁵²		< 100.0			6,000(F)*
Endosulfan		0.0087 (c) ⁵³		0.056 (c) ⁵⁴					
Endosulfan Alpha-		0.0087 (c) ⁵⁵		0.056 (c) ⁵⁶					
Endosulfan Beta-		0.0087 (c) ⁵⁷		0.056 (c) ⁵⁸					
Endrin		0.0023 (c) ⁵⁹		0.0023 (c) ⁶⁰		< 100.0			1,000(F)*
Endrin Aldehyde									significant bioaccumulation expected
Heptachlor		0.0036 (c) ⁶¹		0.0038 (c) ⁶²					
Heptachlor Epoxide		0.0036 (c) ⁶³		0.0038 (c) ⁶⁴		< 100.0			66,000(I)*; 14,400(F)*; 1,600(PI)
Hexachlorobenzene		129.0 (c) ⁶⁵		3.68 (p,c) ⁶⁶				22.0 (AET) ⁶⁷	1,800(I)*; 1,200(F)*
Hexachlorobutadiene		32.0 (a) ⁶⁸		9.3 (c) ⁶⁹				11.0 (AET) ⁷⁰	
Hexachlorocyclohexane		0.34 (a) ⁷¹		100.0 (a) ⁷²		100,000.0 ⁷³			
Hexachlorocyclopentadiene		7.0 (a) ⁷⁴		5.2 (c) ⁷⁵					

Region III, B Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment data for Effects Range- Low, unless otherwise noted		BCF
	Marine		Fresh						
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
Hexachloroethane	940.0 (a) ⁷⁶		540.0 (c) ⁷⁷						
Keponc		7.0 (a) ⁷⁸		7.0 (a)					9,750(F)*;
Lindane		0.16 (a) ⁷⁹		0.08 (c) ⁸⁰	< 100.0				183(I)*; 1,613(F)*
Methoxychlor	0.03 (c) ⁸¹		0.03 (c) ⁸²		< 100.0				
Mirex	0.001 (c) ⁸³		0.001 (c) ⁸⁴						2,200(Pl)*; 2,580(F)*; 71,400(I)
Pentachlorobenzene	129.0 (c) ⁸⁵		50.0 (c) ⁸⁶		100.0				3,400(F)*
1,2,4,5-Tetrachlorobenzene	129.0 (c) ⁸⁷		50.0 (c) ⁸⁸		100.0				
Toxaphene	0.0002 (c) ⁸⁹		0.0002 (c) ⁹⁰						
Tribromomethane		1,000.0 (a) ⁹¹		11,000 (a) ⁹²		1,147.0 mg/kg ⁹³			37.4(F-estimated)*
2,4,6-Trichloroaniline		1,000.0 (a)		1,000.0 (a) ⁹⁴					
SEMI-VOLATILE - ORGANOPHOSPHATES									
Chlorpyrifos	0.0056 (c) ⁹⁵		0.041 (c) ⁹⁶						
Malathion	0.1 (c) ⁹⁷		0.1 (c) ⁹⁸						
Parathion Mixture				0.013 (c) ⁹⁹			31.0 (AET)* ¹⁰⁰		
SEMI-VOLATILE - PHENOLICS									
2-Chlorophenol			970.0 (a)		100.0				
2,4-Dichlorophenol			365.0 (c) ¹⁰¹		100.0				
2,6-Dichlorophenol					100.0				
2,4-Dimethylphenol			2,120.0 (a) ¹⁰²		100.0		29.0 (AET)* ¹⁰³		151(I)*
Dinitrophenol	4,850.0 (a) ¹⁰⁴		150.0 (c) ¹⁰⁵		100.0				
2-Methyl Phenol [O-Cresol]					100.0		63.0 (AET)* ¹⁰⁶		

Region III BTA Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment		BCF
	Marine		Fresh				data for Effects Range-Low, unless otherwise noted		
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
4-Methyl Phenol [p-Cresol]						100.0		670.0 (AET)* ¹⁰⁷	
4-Nitrophenol		4,850.0 (a) ¹⁰⁸		150.0 (c) ¹⁰⁹		100.0			
Pentachlorophenol		7.9 (c)* ¹¹⁰		13.0 (pH, c)* ¹¹¹		100.0		360.0 (AET)* ¹¹²	
Phenol		5,800.0(a) ¹¹³		79.0 (a) ¹¹⁴		100.0		420.0 (AET) ¹¹⁵	200(Pl)*; 277(I)*; 1.9(F)
2,3,4,6-Tetrachlorophenol						100.0			
2,4,5-Trichlorophenol		11.0 (p,c) ¹¹⁶		63.0 (p,c) ¹¹⁷		100.0			
2,4,6-Trichlorophenol				970.0 (c) ¹¹⁸		100.0			
SEMI-VOLATILE - PHTHALATES									
Butyl Benzyl Phthalate (BBP)		3.4 (c) ¹¹⁹		3.0 (c) ¹²⁰				63.0 (AET) ¹²¹	663(F)
Di(2-Ethylhexyl) Phthalate (DEHP)		360.0 (p,c) ¹²²		30.0 (c)				1300.0 (AET) ¹²³	2,680(F)*; 50(I)*
Diethyl Phthalate (DEP)		3.4 (c) ¹²⁴		3.0 (c) ¹²⁵				200.0 (AET) ¹²⁶	117(F)*
Dimethyl Phthalate (DMP)		3.4 (c) ¹²⁷		3.0 (c) ¹²⁸				71.0 (AET) ¹²⁹	
Dioctyl Phthalate		3.4 (c) ¹³⁰		0.3 (c) ¹³¹				6,200.0 (AET) ¹³²	
N-Butyl Phthalate (DBP)		3.4 (c) ¹³³		0.3 (c) ¹³⁴				1,400.0 (AET) ¹³⁵	
SEMI-VOLATILE - PAHS									
Low Molecular Weight									
Acenaphthene		710.0 (c) ¹³⁶		520.0 (c) ¹³⁷		100.0		16.0 ¹³⁸	
Acenaphthylene		300.0 (a) ¹³⁹				100.0		44.0 ¹⁴⁰	

a - acute; c - chronic; p - proposed; * - h - value is dependant on hardness; pH - value is dependant on pH; F - fish; I - invertebrate; Pl - plant; AET - Apparent Effect Threshold

Region III B1 Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment data for Effects Range- Low, unless otherwise noted		BCF
	Marine		Fresh						
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
Anthracene		300.0 (a) ¹⁴¹		0.1 (c) ¹⁴²		100.0		85.3 ¹⁴³	16,800(F)*; 912(I)*
Fluorene		300.0 (a) ¹⁴⁴		430.0 (c)		100.0		19.0 ¹⁴⁵	short-term expected
Naphthalene		2,300.0 (a) ¹⁴⁶		100.0 (c)		100.0		160.0 ¹⁴⁷	3.0(I,F)*
Phenanthrene		4.6 (p,c) ¹⁴⁸		6.3 (p,c) ¹⁴⁹		100.0		240.0 ¹⁵⁰	
-High Molecular Weight									
Benzo (a) Anthracene		8.13 (c)		6.3 (c)		100.0		261.0 ¹⁵¹	134,248(I)*; 9,200(F)*
Benzo (a) Pyrene		0.21 ng/ml (a)				100.0 ¹⁵²		430.0 ¹⁵³	930(F)*; 5,258(PI)*; 132,248(I)
Chrysene		300.0 (a) ¹⁵⁴				100.0		384.0 ¹⁵⁵	minimal to moderate bioaccumulation expected in aquatic organisms
Dibenzo (a,h) Anthracene		300.0 (a) ¹⁵⁶				100.0		63.4 ¹⁵⁷	-
Fluoranthene		16.0 (c) ¹⁵⁸		3,980.0 (a) ¹⁵⁹		100.0		600.0 ¹⁶⁰	bioaccumulation expected
Pyrene		300.0 (a) ¹⁶¹				100.0		665.0 ¹⁶²	970(F)*
Benzo (b) Fluoranthene		300.0 (a) ¹⁶³				100.0		3,200.0 (AET)*	
Benzo (k) Fluoranthene		300.0 (a) ¹⁶⁴				100.0			
Benzo (ghi) Perylene		300.0 (a) ¹⁶⁵				100.0		670.0 (AET)*	
Creosote (mixture) ¹⁶⁶				3,510.0 (a) ¹⁶⁷					
Indeno (1,2,3-CD) Pyrene		300.0 (a) ¹⁶⁸				100.0		600.0 (AET)*	
2-Methylnaphthalene		300.0 (a) ¹⁶⁹						70.0 ¹⁷⁰	

Endnotes - Semi-Volatiles

1. Reference #1, NOAA.
2. LD₅₀ for rabbit, oral
3. Reference #5, IRIS.
4. Reference #5, IRIS.
5. Reference #2, E.R. Long.
6. Reference #12, USEPA.
7. Reference #5, IRIS.
8. Reference #1, NOAA.
9. reference #6, Freitag.
10. LC₅₀ for fathead minnows, reference #7, Verschueren.
11. Reference #1, NOAA.
12. Reference #1, NOAA.
13. Reference #1, NOAA.
14. Reference #5, IRIS.
15. 96-hr LC₅₀ for 31 day old Pimephales promelas, fathead minnow, reference # 8, Geiger.
16. Reference #5, IRIS.
17. Reference #5, IRIS.
18. Reference # 9, Veith.
19. 96-hr LC₅₀ for Pimephales promelas, fathead minnow; reference #10, Brooke.
20. 24-hr LC₅₀ for goldfish, Carassius auratus; reference # 11, Bridie.
21. LD₅₀ for Redwinged blackbird, Angelaius phoeniceus
22. 96-hr LC₅₀ for sheepshead minnow, Cyprinodon variegatus
23. Reference #5, IRIS.
24. Reference #5, IRIS.

25. Reference #5, IRIS.
26. Reference #5, IRIS.
27. Reference #5, IRIS.
28. Reference #5, IRIS.
29. Reference #1, NOAA.
30. Reference #5, IRIS.
31. Reference #5, IRIS.
32. Reference #5, IRIS.
33. Reference #5, IRIS.
34. 7-hr LD₅₀ mouse inhalation
35. Reference #5, IRIS.
36. Reference #5, IRIS.
37. Oral LD₅₀ for adult male Swiss ICR mice
38. Reference #5, IRIS.
39. Reference #5, IRIS.
40. Reference #1, NOAA.
41. Reference #5, IRIS.
42. 96-hr LC₅₀ for Palaemonetes kadiakensis, glass shrimp
43. Reference #1, NOAA.
44. Reference #5, IRIS.
45. Reference #5, IRIS.
46. Reference #2, E.R. Long.
47. Reference #5, IRIS.
48. Reference #5, IRIS.
49. 96-hr LC₅₀ for Asellus Brevicaudus, sowbugs
50. Reference #2, E.R. Long.

51. Reference #5, IRIS.
52. Reference #5, IRIS.
53. Reference #5, IRIS.
54. Reference #5, IRIS.
55. Reference #5, IRIS.
56. Reference #5, IRIS.
57. Reference #5, IRIS.
58. Reference #5, IRIS.
59. Reference #5, IRIS.
60. Reference #5, IRIS.
61. Reference #5, IRIS.
62. Reference #5, IRIS.
63. Reference #5, IRIS.
64. Reference #5, IRIS.
65. Reference #1, NOAA.
66. Reference #5, IRIS.
67. Reference #1, NOAA.
68. Reference #5, IRIS.
69. Reference #5, IRIS.
70. Reference #1, NOAA.
71. Reference #5, IRIS.
72. Reference #5, IRIS.
73. 100,000 ppb suppresses nitrogen forming bacteria; Reference #4, OHMTADS.
74. Reference #5, IRIS.
75. Reference #5, IRIS.
76. Reference #5, IRIS.

77. Reference #5, IRIS.
78. LC₅₀ for estuarine fish
79. Reference #5, IRIS.
80. Reference #5, IRIS.
81. Reference #5, IRIS.
82. Reference #5, IRIS.
83. Reference #5, IRIS.
84. Reference #5, IRIS.
85. Reference #5, IRIS.
86. Reference #5, IRIS.
87. Reference #5, IRIS.
88. Reference #5, IRIS.
89. Reference #5, IRIS.
90. Reference #5, IRIS.
91. 96-hr static LD₅₀ for Crassostrea virginica, eastern oyster, larvae
92. Reference #5, IRIS.
93. LD₅₀ female rat oral
94. Reference #5, IRIS.
95. Reference #5, IRIS.
96. Reference #5, IRIS.
97. Reference #5, IRIS.
98. Reference #5, IRIS.
99. Reference #5, IRIS.
100. Reference #1, NOAA.
101. Reference #5, IRIS.
102. Reference #5, IRIS.

103. Reference #1, NOAA.
104. Reference #1, NOAA.
105. Reference #5, IRIS.
106. Reference #1, NOAA.
107. Reference #1, NOAA.
108. Reference #1, NOAA.
109. Reference #1, NOAA.
110. Reference #5, IRIS.
111. Reference #5, IRIS.
112. Reference #1, NOAA.
113. Reference #5, IRIS.
114. LD₅₀ value for minnows
115. Reference #1, NOAA.
116. Reference #5, IRIS.
117. Reference #5, IRIS.
118. Reference #5, IRIS.
119. Reference #1, NOAA.
120. Reference #5, IRIS.
121. Reference #1, NOAA.
122. Reference #5, IRIS.
123. Reference #1, NOAA.
124. Reference #1, NOAA.
125. Reference #5, IRIS.
126. Reference #1, NOAA.
127. Reference #1, NOAA.
128. Reference #5, IRIS.

129. Reference #1, NOAA.
130. Reference #1, NOAA.
131. Reference #4, OHMTADS.
132. Reference #1, NOAA.
133. Reference #1, NOAA.
134. Reference #4, OHMTADS.
135. Reference #1, NOAA.
136. Reference #1, NOAA.
137. Reference #1, NOAA.
138. Reference #2, E.R. Long.
139. Reference #5, IRIS.
140. Reference #2, E.R. Long.
141. Reference #5, IRIS.
142. Protozoan, Paramecium caudatum.
143. Reference #2, E.R. Long.
144. Reference #1, NOAA.
145. Reference #2, E.R. Long.
146. Reference #5, IRIS.
147. Reference #2, E.R. Long.
148. Reference #5, IRIS.
149. Reference #5, IRIS.
150. Reference #2, E.R. Long.
151. Reference #2, E.R. Long.
152. Mice treated with this dose for 197 days showed stomach tumors
153. Reference #2, E.R. Long.
154. Reference #5, IRIS.

155. Reference #2, E.R. Long.
156. Reference #5, IRIS.
157. Reference #2, E.R. Long.
158. Reference #5, IRIS.
159. Reference #5, IRIS.
160. Reference #2, E.R. Long.
161. Reference #5, IRIS.
162. Reference #2, E.R. Long.
163. Reference #5, IRIS.
164. Reference #5, IRIS.
165. Reference #5, IRIS.
166. Creosote is a mixture of many organic compounds, of which PAHs are a large proportion
167. 24-hr TL50 for goldfish, Crassius auratus; reference #13, USEPA.
168. Reference #5, IRIS.
169. Reference #1, NOAA.
170. Reference #2, E.R. Long.

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11. Bridie AL et al; Water Res 13 (7): 623-6 (1979).
12. USEPA; Ambient Water Quality Criteria Doc: Polychlorinated Biphenyls p.B-22 (1980) EPA 440/5-80-068.
13. USEPA; Health and Environmental Effects of Creosote p.53-12 (1980) EPA No.53

Region III BTA Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment		BCF
	Marine		Fresh				data for Effects Range-Low, unless otherwise noted		
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
VOLATILE - AROMATIC / HALOGENATED									
Benzene	20,000.0 (c)	700.0 (c) ¹	20,000.0 (c)	5,300.0 (a) ²		100.0			77 (F)
Bis (2-Chloroethoxy) Methane		6,400.0(c) ⁴		11,000.0 (a) ⁵					
Carbon Tetrachloride		50,000.0 (a) ⁶		35,200.0 (a) ⁷		< 300.0			1.48(F)
Chlorobenzene	341,000.0 (a) ⁸	129.0 (c) ⁹	6,630.0 (a) ¹⁰	50.0 (c) ¹¹		100.0			
Chlorodibromomethane		6,400.0 (c) ¹²		11,000.0 (a) ¹³					
Chloroform				1,240.0 (c) ¹⁴		< 300.0			1.4(F)
1,2-Dibromoethane				18,000.0 (a) ¹⁵	5,000.0 ¹⁶				< 1(F)
Dibromomethane		6,400.0 (c) ¹⁷		11,000.0 (a) ¹⁸					
1,2-Dichlorobenzene		129.0 (c) ¹⁹		763.0 (c) ²⁰		< 100.0	35.0 (AET) ^{*21}		560(F)*; 4.17(PI)*
1,3-Dichlorobenzene				763.0 (c) ²²					740(F)*
1,4-Dichlorobenzene		129.0 (c) ²³		763.0 (c) ²⁴		< 100.0	110.0 (AET) ^{*25}		720(F)*
Dichlorobromomethane		6,400.0 (c) ²⁶		11,000.0 (a) ²⁷					
Dichlorodifluoromethane		6,400.0 (c) ²⁸		11,000.0 (a) ²⁹					
1,1-Dichloroethane		320,000.0 (a) ³⁰		160,000.0 (a) ³¹		< 300.0			1.2(F)*
1,2-Dichloroethane		113,000.0 (a) ³²		20,000.0 (c) ³³		870.0 mg/kg ³⁴			0.3(F)*
1,1-Dichloroethylene	712,000.0 (a) ³⁵	224,000 (a) ³⁶	798,000.0 (a) ³⁷	11,600.0 (a) ³⁸					no significant bioaccumulation
1,2-Dichloroethylene cis and trans		224,000.0 (a) ³⁹		11,600.0 (a) ⁴⁰		< 300.0			cis - 15; trans - 22
Dichloropropene		790.0 (a) ⁴¹		244.0 (c) ⁴²		<300.0			7(F)*
1,3-Dinitrobenzene			1,200.0 (a)						
Ethylbenzene		430.0 (a) ⁴³		32,000.0 (a) ⁴⁴		100.0	10 (AET) ⁴⁵		37.5(F)*
Ethylene Dichloride		113,000.0 (a) ⁴⁶		20,000.0 (c) ⁴⁷					

Region III B Screening Levels

(all values in ppb, unless otherwise noted)

Contaminant	Aquatic				Soil		Sediment		BCF
	Marine		Fresh				data for Effects Range-Low, unless otherwise noted		
	Flora	Fauna	Flora	Fauna	Flora	Fauna	Flora	Fauna	
Methylene Chloride	6,400.0 (c) ⁴⁸		11,000.0 (a) ⁴⁹		< 300.0				5(estimated)
Pentachloroethane	281.0 (c) ⁵⁰		1,100.0 (c) ⁵¹						
Propylene Dichloride	3,040.0 (c) ⁵²		5,700.0 (c) ⁵³		< 300.0				
Styrene					100.0				13.5(F) [*]
Tetrachloroethane	6,230.0 (a) ⁵⁴	9,020.0 (a) ⁵⁵	146,000.0 (a) ⁵⁶	2,400.0 (c) ⁵⁷	< 300.0				1(F) [*]
Tetrachloroethylene	450.0 (c) ⁵⁸		840.0 (c) ⁵⁹		< 300.0			57 (AET) ⁶⁰	49(F) [*]
Toluene		1,050.0 (a) ⁶¹		17,000.0 (a) ⁶²	100.0				26(F) [*]
Trichlorobenzene	129.0 (c) ⁶³		50.0 (c) ⁶⁴		< 100.0			40.0	2,800(F) [*]
Trichloroethane	31,200.0 (a) ⁶⁵		9,400.0 (c) ⁶⁶		< 300.0			31 (AET) ⁶⁷	8.9(F) [*]
Trichloroethylene	2,000.0 (a) ⁶⁸		21,900.0 (c) ⁶⁹		< 300.0				39(F) [*]
Trichlorofluoromethane	6,400.0 (c) ⁷⁰		11,000.0 (a) ⁷¹						
Vinyl Chloride	224,000.0 (a) ⁷²		11,600.0 (a) ⁷³		300.0				40(Pl) [*] ; 10(F) [*]
Xylene		13,500.0 (a) ⁷⁴ , 6,000.0 ⁷⁵		13,000.0 (a) ⁷⁶ , 6,000.0 ⁷⁷		<100.0		40 (AET) ⁷⁸	6(l) [*] , 2.2(F) [*]
VOLATILE - MISCELLANEOUS									
Acetone				9,000,000.0 (a)					0.69(F) [*]
Acrolein	55.0 (a) ⁷⁹		21.0 (c) ⁸⁰						344(F)
Acrylonitrile			2,600.0 (c) ⁸¹						48(F)
Carbon Disulfide		2.0 (c) ⁸²		2.0 (c) ⁸³					

Endnotes - Volatiles

1. Reference #5, IRIS.
2. Reference #5, IRIS. LC₅₀ mortality for Rainbow trout, reference #4, Degraeve.
3. Striped bass, reference #6, Korn.
4. Reference #5, IRIS.
5. Reference #5, IRIS.
6. Reference #5, IRIS.
7. Reference #5, IRIS.
8. 96-hr EC₅₀ value for the alga, Skeletonema costatum
9. Reference #5, IRIS.
10. 96-hr EC₅₀ for the alga, Selenastrum capricornutum
11. Reference #5, IRIS.
12. Reference #5, IRIS.
13. Reference #5, IRIS.
14. Reference #5, IRIS.
15. 48-hr LC₅₀ for Lepomis macrochirus
16. Reference #4, OHMTADS.
17. Reference #1, NOAA.
18. Reference #1, NOAA.
19. Reference #1, NOAA.
20. Reference #5, IRIS.
21. Reference #1, NOAA.
22. Reference #5, IRIS.
23. Reference #1, NOAA.
24. Reference #1, NOAA.

25. Reference #1, NOAA.
26. Reference #5, IRIS.
27. Reference #5, IRIS.
28. Reference #5, IRIS.
29. Reference #5, IRIS.
30. 24-hr TLm for Artemia salina, brine shrimp
31. 24-hr LC₅₀ for Lagodon rhomboides, pinperch
32. 96-hr LC₅₀ for Mysid shrimp; Reference # 5, IRIS.
33. Reference #5, IRIS.
34. LD₅₀ mouse oral
35. 96-hr EC₅₀ for Skeletonema costatum
36. Reference #5, IRIS.
37. 96-hr EC₅₀ for Selenastrum capricornutum
38. Reference #5, IRIS.
39. Reference #5, IRIS.
40. Reference #5, IRIS.
41. Reference #5, IRIS.
42. Reference #5, IRIS.
43. Reference #5, IRIS.
44. Reference #5, IRIS.
45. Reference #1, NOAA.
46. Reference #5, IRIS.
47. Reference #5, IRIS.
48. Reference #5, IRIS.
49. Reference #5, IRIS.
50. Reference #1, NOAA.

51. Reference #1, NOAA.
52. Reference #1, NOAA.
53. Reference #1, NOAA.
54. 96-hr EC_{50} for Skeletonema costatum
55. 96-hr LC_{50} for Mysidopsis bahia, Mysid shrimp, Reference #5, IRIS.
56. 96-hr EC_{50} for Selenastrum capricornutum
57. Reference #5, IRIS.
58. Reference #5, IRIS.
59. Reference #5, IRIS.
60. Reference #1, NOAA.
61. LC_{50} value for the Pacific oyster, Crassostrea gigas
62. Reference #5, IRIS.
63. Reference #5, IRIS.
64. Reference #5, IRIS.
65. Reference #1, NOAA.
66. Reference #5, IRIS.
67. Reference #1, NOAA.
68. Reference #5, IRIS.
69. Reference #5, IRIS.
70. Reference #5, IRIS.
71. Reference #5, IRIS.
72. Reference #5, IRIS.
73. Reference #5, IRIS.
74. 96-hr LD_{50} for rainbow trout, Salmo gairdneri
75. Suggested permissible ambient goal set forth by EPA based on health effects
76. 24-hr LD_{50} for goldfish, Carassius auratus

77. Suggested permissible ambient goal set forth by EPA based on health effects

78. Reference #1, NOAA.

79. Reference #5, IRIS.

80. Reference #5, IRIS.

81. Reference #5, IRIS.

82. Reference #5, IRIS.

83. Reference #5, IRIS.

References

- NOAA Screening Guidelines for Inorganics. Hazmat Report 94-8.
HSDB (through February 1995). Hazardous Substance Data Base. National Library of Medicine, National Toxicology Information Program, Bethesda, MD. June 15, 1995.
3. OHMTADS. 1987. Oil and Hazardous Materials Technical Assistance Data System. Washington DC: Environmental Protection Agency - National Institute of Health. July 19, 1995.
 4. Degraeve, G.M., R.G.Elder, D.C.Woods, and H.L.Bergman. 1982. Effects of Naphthalene and Benzene on Fathead Minnows and Rainbow Trout. Arch. Environ. Contam. Toxicol. 11:487-490.
 5. IRIS (through May 1995). Integrated Risk Information System (database). Ambient Water Quality Criteria, Aquatic Organisms. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, OH. July 19, 1995.
 6. Korn, S., N.Hirsch, and J.W. Struhsaker. 1976. Uptake, Distribution, and Depuration of ¹⁴C-Benzene in Northern Anchovy, *Engraulis mordax*, and Striped Bass, *Morone saxatilis*. U.S. Natl. Mar. Serv. Fish. Bull. 74(3):545-551.